ELECTRICAL CONSTRUCTION

AN ELEMENTARY COURSE FOR VOCATIONAL SCHOOLS

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FOREWORD

A realization of the difficulties involved in obtaining drawings which show clearly the principles of electrical construction, has led to the preparation of the following lessons or problems. The author's experience as a teacher has shown conclusively that many hours of the teacher's limited time are expended uselessly in preparing such drawings and blueprints. The primary aim, therefore, in placing this series of problems, with the accompanying drawings, before the public is to save the teachers, so far as possible, this needless labor of making such drawings and blueprints. This arrangement of the material may further prove of value to the students for reference purposes.

Thruout, the problems are graduated in the order of difficulty they present, and, in most instances, each succeeding lesson or problem involves the outstanding features of those immediately preceding. Experience has shown that such sequential arrangement is a positive aid toward understanding the principles involved.

Teachers using this book will violate one of the most fundamental principles of teaching unless they consider these drawings merely as an effective means of revealing the principles involved and in no sense a standard to be set up and maintained before the class. The application of these must be left to the individual teachers and must necessarily vary in accordance with (1) commercial practices and (2) the individualities of the different students. There is slight probability that this arrangement, together with the fore-notes, could result other than satisfactorily in the hands of a wide-awake teacher.

It will be noted that in connection with the first lesson or problem of each series the operations, tools, and materials are listed; only new or additional ones are mentioned in connection with succeeding lessons in the same series. It will be found advisable to have the student fill in the blank spaces in each lesson with the names of the operations, tools, and materials for that particular piece of work; also to answer the various questions.

The loose-leaf arrangement of the book, it is hoped, will serve a two-fold purpose: (1) That of greater convenience for any teacher who may wish to give the students one lesson sheet at a time to be filled in and answered after he has completed the work on that particular problem. In this way the sheet will serve as a record of each individual problem. (2) That the student can add extra sheets during the course or at any future time.

The author takes this opportunity of acknowledging his indebtedness to Mr. D. J. MacDonald, Head of the Department of Pedagogy, Buffalo State Normal School, who gave valuable assistance in arranging the book.

WALTER B. WEBER.

Buffalo, N. Y.
May, 1916.

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ELECTRIC LIGHT CIRCUITS

KNOB AND TUBE WORK

CONDUIT WORK

WOOD MOLDING WORK

METAL MOLDING WORK

Telephony

Motors and Generators

To Teacher

The following problems should be given to the student after he has completed the one indicated by the number placed before the statement of the problem. These should be worked out without assistance from the instructor, since the principles involved are almost identical with those involved in the problems previously completed:

15. Connect six dry cells in series multiple, so as to get approximately 4½ volts and 50 amperes.

23. Make a double-branch tap.

25. Make a single-stroke bell from a vibrating bell.

32. Connect a two-wire return call system, using three-point back-contact push-buttons.

37. Change wiring so as to save one wire.

38. Change wiring so as to save one wire.

40. Connect one point switch so that when the switch is off the bell will ring, and not ring when the switch is on.

41. Change extension bell from vibrating to single-stroke.
Connect a return call in connection with this system.
Connect two annunciators in (a) series, (b) multiple.

42. Change the two-point switches to one three-point switch.

43. Change two-point button to a single-pole switch.

52. Change connections so that the switch will operate two lights, while the other two burn continuously.

55. Change connections so as to have a closet system of wiring.

57. Change single-pole to three-way switch.

59. Include another double-pole double-throw switch for reversing the current.

61. Mount one three-way and one four-way switch with a light above each; connect same. (Snap three-way switch, light above burns, four-way light goes out; snap four-way, light above burns, three-way light goes out.)

62. Connect two more four-way switches in the circuit.
Show the lights burning with the switches in four different positions.

63. Connect two more single-pole switches in the circuit.

64. Change connections so that one light will burn at the first snap of the switch, and three lights at the second snap.

66. Change connections so that a single-pole may take the place of the double-pole master switch by changing one three-way of the three-way switch circuit to a four-way switch.

71. Mount same for base plug attachment.

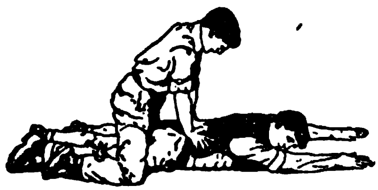
87. Connect two phones, using one set of battery and three lines.
Connect three phones, using three sets of batteries and two lines.
Connect three phones, using one set of battery and three lines.

Safety Rules

1. Do not depend on the insulation of a wire; it may be faulty.
2. All lines should be considered as alive and dangerous unless they are positively known to be dead.
3. Never leave joints or loose ends of wire untaped.
4. When working overhead keep tools and material not in use in proper receptacles; do not throw tools or material to the ground.
5. Never climb a ladder unless it is well secured from slipping at both ends.
6. Promptly report any broken or unsafe tools or equipment.

First Aid Treatment for Electric Shock

In the treatment given for electric shock the first and most important thing, and that which requires great care on the part of the rescuer, is to free the patient from the circuit; then, if he is unconscious, lay him on his stomach with arms extended forward, loosen his clothing, and provide plenty of fresh air by turning his face sidewise and



drawing his tongue out. Straddle the patient as shown, and, with hands resting on his lower ribs, swing forward and gradually bring your weight on the patient's back; then immediately remove pressure by swinging backward. Repeat this movement every five seconds and continue it for hours, if necessary, or until the patient breathes naturally. In the meantime send for a doctor, and do not, in any case, give the patient liquids until he is fully conscious.

Shop Rules

1. Be punctual and regular.
2. Pay strict attention to orders.
3. Mind your own business.
4. Keep your surroundings clean.
5. Avoid throwing oily waste where it may cause fire.
6. Be careful of gasoline.
7. Drive a screw with a screw-driver.
8. Be sure all splices are electrically and mechanically secure before soldering and taping.
9. Use all short pieces of wire.
10. Do not think that you are the only one who needs the instructor's attention.

11. Learn to work in harmony with your mates, remembering that their rights and privileges are the same as yours.

12. Give special attention to what is going on at the present time; by so doing you may prevent the spoiling of work and perhaps serious injury to yourself.

13. Do not pass remarks concerning others' troubles; you may soon have some of your own.

14. Be sure you are right; then go ahead.

Practical Hints

1. An unglazed porcelain tube makes a good whetstone for sharpening a jackknife.

2. Soapstone applied to wires makes them pull more easily through conduit.

3. A piece of sheet lead rolled up makes a good expansion shield.

4. The difficulty of cutting flexible tubing (circular loom) can be overcome by wetting the knife blade.

5. A coarse file placed in a vice or monkey wrench will grip conduit in case of emergency.

6. To change the tone of an electric bell, saw a slot in the gong with a hack-saw.

7. To distinguish the front door bell, place one bell close to the other so that the hammer will strike both bells, making it sound like a telephone bell.

8. To determine which is negative or positive, insert both sides of a circuit in a non-metallic vessel containing water and a little salt. Hydrogen gas will form on the negative wire.

9. Another way is by placing both leads about one-half inch apart on a piece of wet blueprint paper; the negative will show a white spot.

10. A piece of thread used as a fish wire can be drawn through a small angled arm of an electric fixture by quick intakes of breath.

11. Another method is to take a piece of pull socket chain, attach to it a piece of thread and let it slide through the fixture arm.

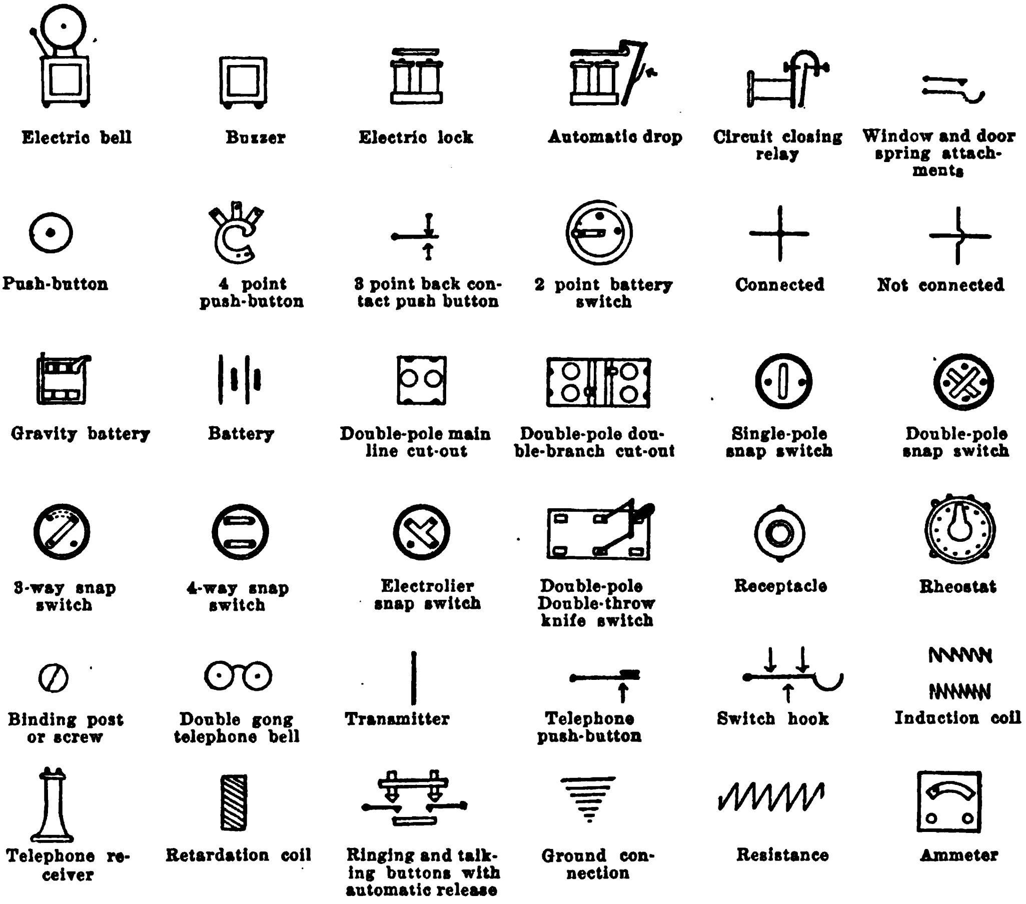
12. To prevent plaster from falling, when boring a hole in the ceiling, place a canopy made of paper or cardboard over the bit to receive falling plaster.

13. When boring holes in wood molding, bore them in pairs about one inch apart so that if you strike an opening between laths with one hole, you can use the other.

14. To hold a rubber bushing in a canopy, heat the threaded end of the bushing with a match or candle and it will quickly soften. Before hardening press out edges with thumb, thus forming a shoulder and locking the bushing.

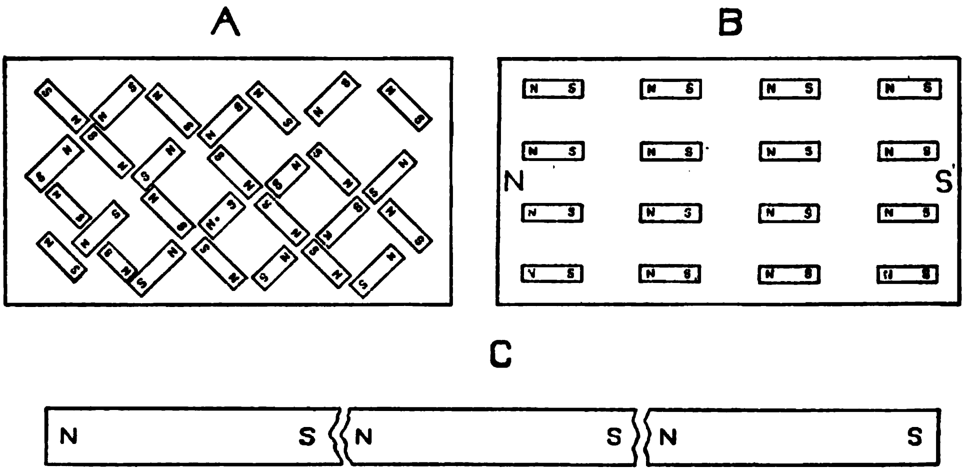
15. A good way to locate a short-circuit, is to take out one of the fuses and put a lamp in its place; the light will then burn, giving current to the line, the lamp going out when trouble is found.

Key to Symbols



B. Battery	R.B. Ringing battery	T.B. Talking battery	L. Line	H. Home line	Dry cell
A. Ampere	V. Volt	S.P. Single-pole	D.P. Double-pole	D.P.D.T. Double-pole Double-throw	S.B. Single-branch
D.B. Double-branch	S.B.R.C. Single-braid Rubber-covered	D.B.R.C. Double-braid Rubber-covered	C.P. Candle power	H.P. Horse power	R. Resistance

PROBLEM 1



Problem

Molecular theory of magnetism.

Principle

Every molecule or particle of iron or steel is, by nature, a magnet. These highly magnified polarized molecules, as shown in A, arrange themselves in geometrical figures, in accordance with the law that unlike poles attract each other, but they produce no external magnetism.

When influenced by a permanent or electro magnet, they arrange themselves in parallel form, as shown in B, breaking up the closed local magnetic circuits, making a north pole at one end and a south pole at the other, producing external magnetism.

A magnet is said to be saturated or has its greatest strength when the molecules are turned on their axis until they are all arranged symetrically.

Residual magnetism is that magnetism which remains in the iron after the influencing magnet has been removed. This is due to the particles not returning to their original position, producing a slight trace of external magnetism, depending on the hardness of the iron.

The permanent magnet C may be broken into any number of parts and each part, no matter how small, will have a north and a south pole.

Object

To prove the presence of magnetism by the molecular theory.

Questions

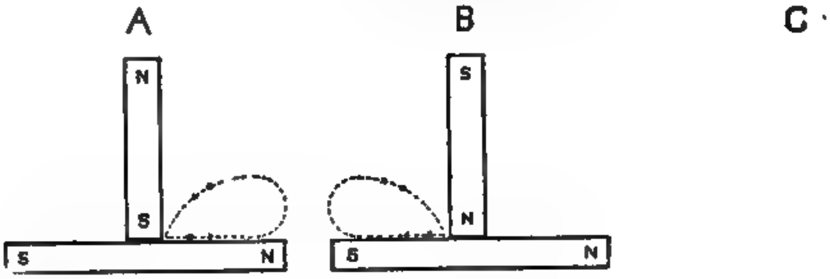
What is meant by polarity?

Name the two poles of a magnet?

How are the poles of a magnet located?

Of what particular value is residual magnetism?

PROBLEM 2



Problem

Construction and operation of a permanent magnet.

Principle

A permanent magnet must be made of very hard steel. One pole always induces the opposite pole in any magnetizable body at the point where the pole leaves the body.

To produce a good bar magnet, each half must be magnetized separately, as shown in A and B.

A horseshoe magnet, C, will lift three to four times as much as a bar magnet of equal weight.

The strength of a permanent magnet is impaired when subjected to vibration, severe shocks, or heat.

The soft iron keeper, D, when placed in the position as shown in C, will lengthen the life of the magnet but must not be in position as shown when the horseshoe magnet is being magnetized.

Object

To show the method and material used in making a good permanent magnet.

Questions

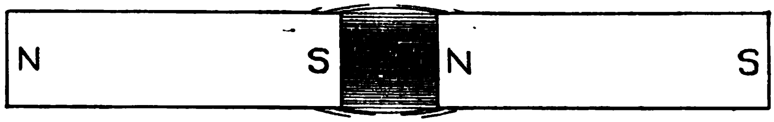
Why must the steel be hardened before magnetizing?

Why is the strength of a permanent magnet impaired by vibration, shocks or heat?

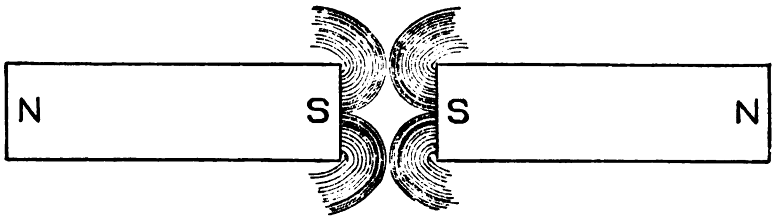
Why does the keeper lengthen the life of a horseshoe magnet?

Where are permanent magnets used commercially?

PROBLEM 3



A



B

Problem

Attraction and repulsion of magnets.

Principle

Like poles repel and unlike poles attract each other.

Magnetic field has a definite direction, as does electric current, from the north to the south pole.

Magnetic field, or surrounding medium, consists of conventional magnetic lines of force which complete their circuit independently and never cut across or merge into each other.

A illustrates the magnetic field of two bar magnets with unlike poles attracting each other.

B illustrates the magnetic field of like poles repelling each other.

Magnetic Substances	Non-magnetic Substances	
Iron	Zinc	Gold
Steel	Tin	Silver
Nickel	Lead	Mercury
Cobalt	Copper	

Object

To show that magnets have the property of attracting and repelling magnetizable articles as well as themselves.

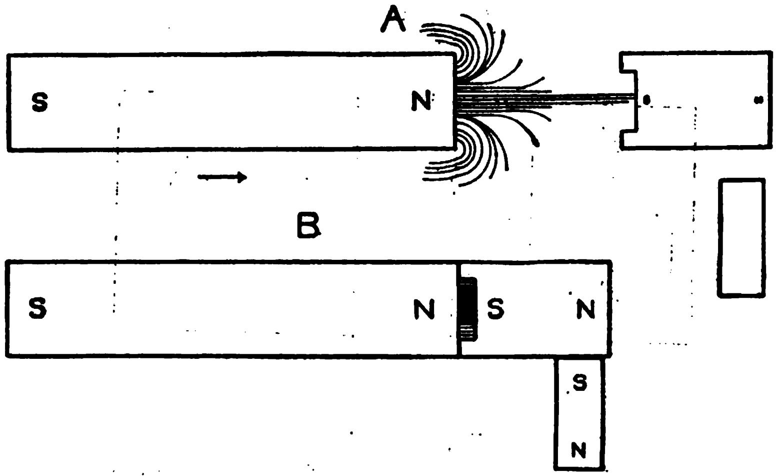
Questions

How could three bar magnets be put together so as to make a compound magnet?

For what are compound magnets used?

What is meant by attraction and repulsion?

PROBLEM 4



Problem

Magnetic induction.

Principle

The effect of magnetic induction varies inversely as the square of the distance.

The magnet first magnetizes the neutral piece of iron and then attracts, as shown in A and B.

The power of magnetic induction is greatest when the bars are touching as shown in B.

The north pole of any magnet induces a south pole into the neutral bar of iron, and vice versa.

A temporary magnet is a piece of iron under the influence of a permanent or electro magnet.

Magnetic induction proves that magnetism cannot be insulated.

Object

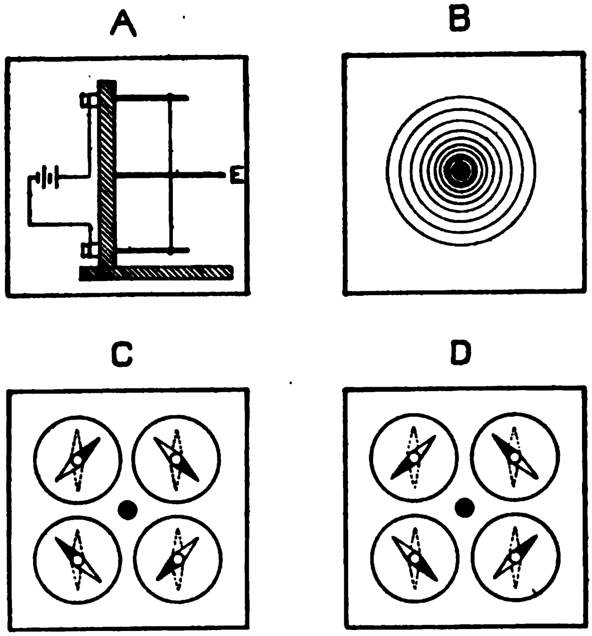
To show how a neutral piece of iron may become a temporary magnet having two unlike poles and a neutral point, even tho it does not come in actual contact with a magnet.

Questions

What is the difference between a permanent and a temporary magnet? Give example of each.

Name some commercial uses of magnetic induction.

PROBLEM 5



Problem

Magnetic field around a wire.

Principle

The lines of force about a charged wire represent concentric circles, whose centers are the wire itself, as shown in B.

Lines of force tend to arrange themselves parallel with each other.

On a vertical wire, with the current flowing from top to bottom, as shown in A, the lines of force will circle the wire in a clockwise direction, as shown in C.

On a vertical wire, with the current flowing from bottom to top, the lines of force will circle the wire in a counter clockwise direction, as shown in D. B, C, and D represent the top view of plate E upon which the iron filings and compasses are placed.

Object

To prove the presence of a magnetic field around a wire carrying electric current.
To deduce the law of relation between lines of force and direction of current.

Questions

What is a magnetic field?

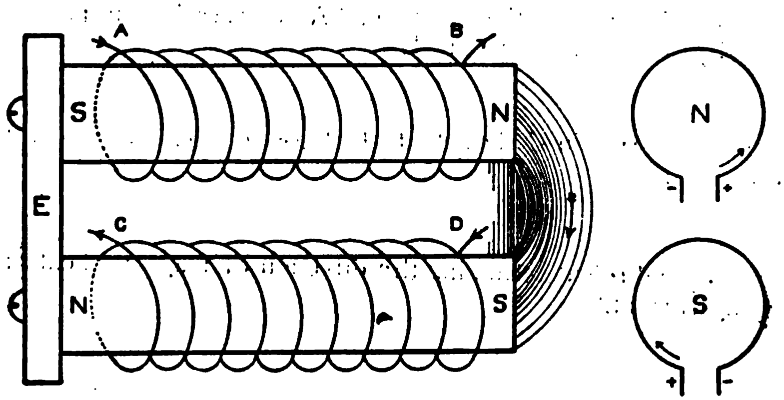
What is a magnetic needle and what is it used for?

What do you understand by the statement "A compass has its polarity reversed", and how would you correct this reversal?

How do the compasses in C show that the lines of force are circling the wire in a clockwise direction?

Give the right-hand rule determining the direction of magnetic field around a conductor carrying current.

PROBLEM 6



Problem

Construction and operation of an electro magnet.

Principle

The strength of the magnetism depends upon: The number of loops or turns of wire; the strength of the current in each turn (turns multiplied by amperes equals ampere turns); dimension of the iron bar or core in length, breadth, and thickness; permeability of the metal used.

Permeability is the ratio between the strength of a magnetic field, with and without iron in the field, the lines of force in the latter case passing through the air. (The permeability of iron is one thousand times greater than air.)

Reluctance of a magnetic circuit may be compared with the resistance of an electric circuit, and is governed by length, breadth, thickness and permeability of the metal.

The current must pass around the loops of wire in a clockwise direction to produce a south pole toward the observer, and vice versa.

Object

To show that an electro magnet produces a magnetic field. To show the relation between the direction of current and the polarity of a magnet.

Questions

Why is the iron core used in an electro magnet?

What is the law of relation between the flow of current about an electro magnet and the polarity?

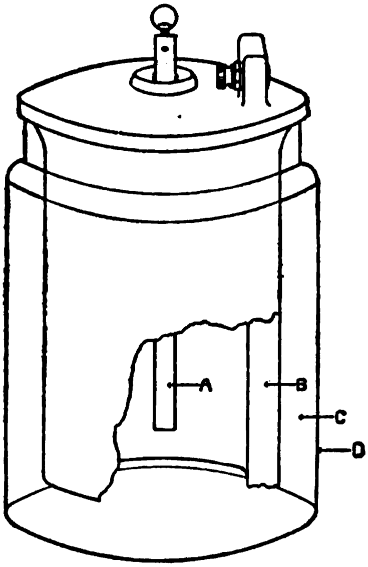
Name three commercial uses of electro magnets.

How does an electro magnet differ from a permanent magnet, and in what respects are they similar?

Why is yoke E placed across the cores?

What ends—A, B, C, or D—must be connected together, and to which must the current be attached to produce the poles designated.

PROBLEM 7



Problem

Construction and action of carbon cylinder cell (single fluid solid depolarizer).

Principle

Energy is produced by chemical action of the electrolyte on the elements, or rapid giving off of hydrogen from the surface of the carbon.

Local Action—is constant and represents an absolute waste, or decomposition of the zinc.

Voltic Action—occurs only when the current is flowing. It is caused by the chemical action between the electrolyte and the elements.

Meter Reading—1½ volts and an initial current of 7 amperes.

A—Positive element, or negative terminal, is the zinc rod.

B—Negative element, or positive terminal, is the carbon cylinder.

C—Electrolyte, or exciting fluid, is sal ammoniac — four ounces dissolved in enough water to fill jar—including elements—once inch from the top.

D—Glass Jar—container for elements and electrolyte.

Object

To show the construction and action of a wet cell that can be easily recharged. This cell is used for intermittent work.

In the list of elements below (any two of which may be used), the greatest voltage is secured from those farthest apart in the list. In a practical battery, however, the cost of the elements and the convenience of handling determine which are best adapted.

1. Aluminum
2. Zinc
3. Tin
4. Cadmium
5. Lead
6. Antimony
7. Bismuth
8. German silver
9. Brass
10. Mercury
11. Iron
12. Steel
13. Copper
14. Silver
15. Gold
16. Carbon
17. Platinum
18. Iron sulphite
19. Manganese dioxide
20. Lead peroxide

Questions

How would you know when a carbon cylinder cell needed recharging?

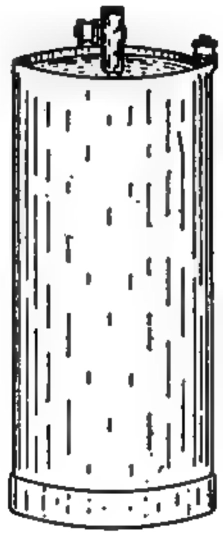
How would you recharge this cell?

What are these cells used for?

What causes the decomposition of the zinc?

How could this decomposition be prevented?

PROBLEM 8



Problem

Construction and action of a dry cell (single fluid, semi-solid depolarizer).

Principle

Energy is produced by chemical action of the electrolyte on the elements.

Meter Reading—1½ volts and an initial current of 25 amperes.

A—Sealing compound is placed on top so that the electrolyte will not evaporate.

B—Negative element, or positive terminal, is the carbon rod.

C—Absorbing material may be mineral wool, sawdust, asbestos, etc.

Electrolyte, or exciting fluid, may be sal ammoniac, zinc chloride, or common salt.

Depolarizer is compound manganese and is used to absorb the hydrogen.

D—Blotting paper is used to absorb the electrolyte, thereby giving good contact surface to the zinc.

E—Zinc containing case, positive element negative terminal.

F—Cardboard carton fits over the zinc case and is used to insulate the cells when placed together.

Object

To show the construction and action of a dry cell, to be used for intermittent work only.

Questions

Why is this called a dry cell?

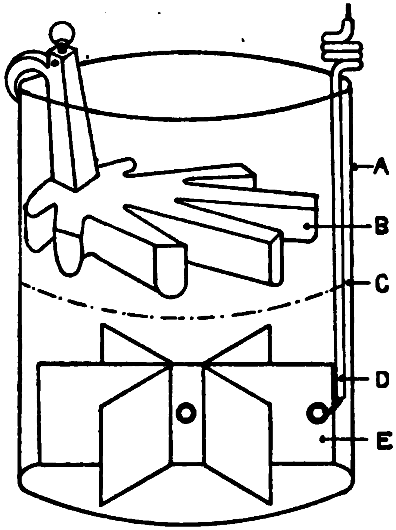
What would happen if the sealing compound became cracked?

How could this cell be temporarily charged?

Why should cell be kept in a dry, cool place?

What are dry cells used for?

PROBLEM 9



Problem

Construction and action of a gravity cell (double fluid).

Principle

Current is produced by chemical action of the solution on the plates.

Polarization is prevented by having some copper sulphate (blue stone) at the bottom of jar.

Cell should be short-circuited for two days to form sulphate of zinc.

Meter reading—One volt and an initial current of one ampere.

A—Glass jar for electrolyte and elements.

B—Positive element (negative terminal) is the crow-foot zinc.

C—Dividing line between the electrolytes. Electrolyte consists of three pounds of sopper sulphate in water, forming a clear blue solution in the bottom and a colorless zinc sulphate solution, which is formed by chemical action, at the top of the cell.

D—Rubber-covered wire, connected with the copper, (positive terminal, negative element) is used to bring the connection to the surface. The rubber covering is to keep the wire from coming in contact with the zinc element and to prevent chemical action.

E—Negative element (positive terminal) is the fan-shaped copper at the bottom of the jar.

Object

To show the construction and action of a gravity cell, to be used for closed circuit work.

Questions

Why is this called a gravity cell?

When does this cell need recharging?

How should this cell be recharged?

For what is this cell used?

PROBLEM 10

A

B

C

D

E

F

G

Problem

Construction and action of a small storage cell.

Principle

Energy is produced by a charging current which causes electrolyte to undergo a chemical decomposition and in turn chemically changes the plates which, when discharged, return to their original condition.

The positive terminal must be connected to the positive terminal of the charging service.

Battery is completely charged when it gases freely or gives a voltage test of about 2.5 volts.

The charging current flows in the opposite direction to that of the discharging.

The voltage should never fall below 1.72 volts, since it will become so badly sulphated that it will be almost impossible to restore the cell to its original condition.

Meter reading—2.5 volts and a rated ampere hour capacity.

NOTE.—Never connect an ammeter across a storage cell.

A—Height of electrolyte which consists of sulphuric acid diluted in pure water to a density of 1.2. A hydrometer is used for this test.

B—Glass jar for electrolyte and elements.

C—Positive plate is made of lead and when charged has a brown or chocolate color.

D—Buttons in the positive plate consist of corrugated lead ribbon rolled up and forced into the lead plate; they are then filled with a paste consisting of red lead and diluted sulphuric acid, and by an electro chemical action they become active material.

E—Negative plate is a lead grid and when charged has a steel gray color.

F—Paste, consisting of litharge and diluted sulphuric acid, pressed into plate and hardened and formed by the same process as the positive plate.

G—Perforated hard rubber separator.

Object

To show the construction and action of a storage cell, which is capable, according to its rating, of giving a high, continuous current.

Questions

When does this cell need recharging?

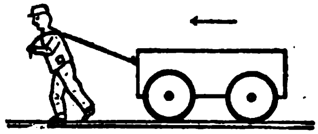
How is the capacity of a storage cell usually expressed?

What causes the plates to sulphate?

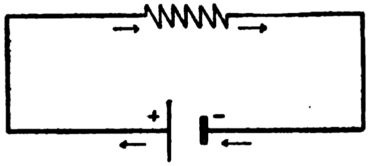
What is an electrolyte?

Why should an ammeter never be connected across a storage cell?

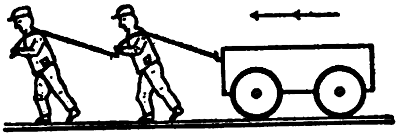
PROBLEM 11



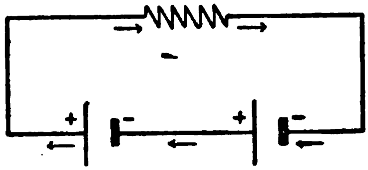
[1]Mechanical illustration of the working of a single cell.



Electrical illustration of the working of a single cell.



Mechanical illustration of the proper working of two cells in series.



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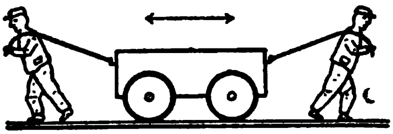
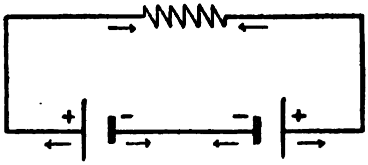


[1]Mechanical illustration of the improper working of two cells in series.



Electrical illustration of the improper working of two cells in series.

Problem

Analogy between mechanical and electrical forces.

Principle

Current always flows from positive to negative terminal.

Object

To establish proper connection.

Tools

Material

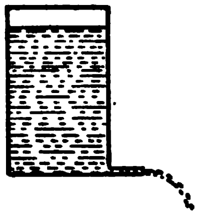
Questions

In which connection would the most current flow?

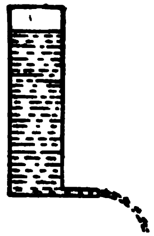
Would any current flow in the last connection? Why?

[1]Illustrations reproduced from Houston & Keenelly's Electrical Engineering Leaflets, by permission of McGraw-Hill Book Co., Inc.

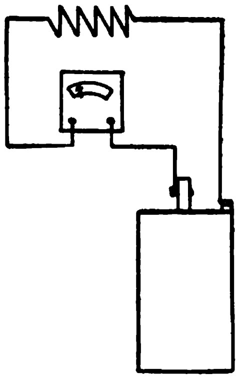
PROBLEM 12



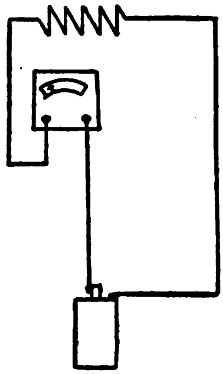
Equal pressure and flow. Large capacity, long service.



Equal pressure and flow. Small capacity, short service.



Equal voltage and resistance. Large capacity, long service.



Equal voltage and resistance. Small capacity, short service.

Problem

Analogy between battery current and water flow.

Principle

Size of cell or tank determines capacity.

Object

Power to do varies directly as the size of cell.

Tools

Material

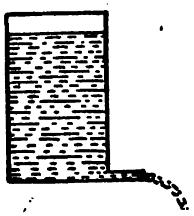
Large and small dry cell, ammeter, and resistance coil.

Questions

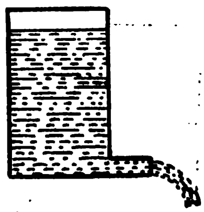
Does the voltage of a cell vary in proportion to size?

How much current, on a short-circuit, should a standard dry cell indicate?

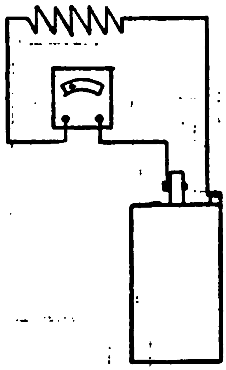
PROBLEM 13



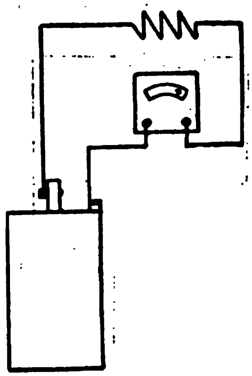
High resistance. Light flow. Long service.



Low resistance. Heavy flow. Short service.



High resistance. Low current. Long service.



Low resistance. High current. Short service.

Problem

Analogy between battery current and water flow.

Principle

Current strength is inversely proportional to the resistance ($C = \frac{E}{R}$).

Object

To avoid having unnecessary resistance in circuit.

Tools

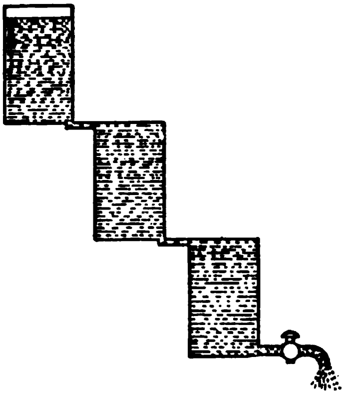
Material

Questions

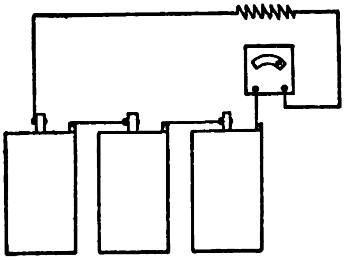
Does increasing the resistance of a circuit increase or decrease the current strength?

Does increasing the cross-sectional area of a wire increase or decrease the current strength?

PROBLEM 14



Tanks in series, pressure of three tanks. High pressure, heavy flow.



Cells in series, pressure of three cells. High voltage, high current.

Problem

Analogy between battery current and water flow.

Principle

Voltage is directly proportional to the number of cells in series.

Object

To increase voltage connect cells in series.

Tools

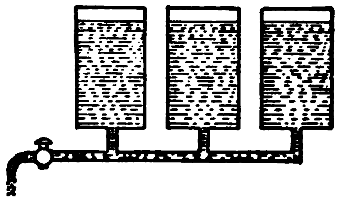
Material

Questions

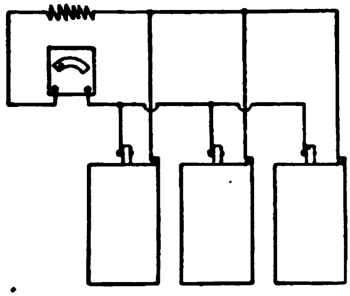
If each cell gives 1½ volts, what would be the voltage of three cells in series?

If each cell gives an initial current of 25 amperes, what would be the initial current of three cells in series?

PROBLEM 15



Tanks in parallel, pressure of one tank. Low pressure, low flow.



Cells in parallel, pressure of one cell. Low voltage, low current.

Problem

Analogy between battery current and water flow.

Principle

Capacity is directly proportional to the number of cells in parallel.

Object

When a circuit requires cells to discharge above normal rate, remedy by connecting cells in parallel.

Tools

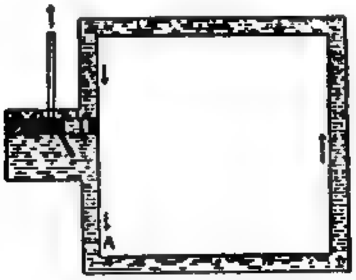
Material

Questions

If each cell gives 1½ volts, what would be the voltage of three cells in parallel?

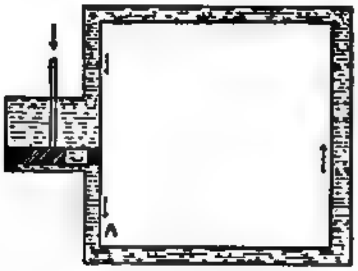
If each cell gives an initial current of 25 amperes what would be the initial current of three cells in parallel? (See fore-notes.)

PROBLEM 16

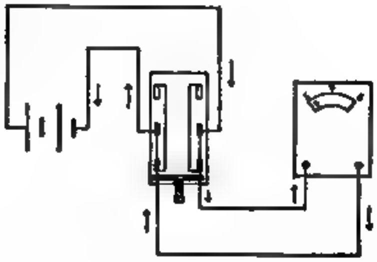


Piston up, valve open, flow toward A.

Switch up, needle deflection, left.



Piston down, valve closed, flow toward A.



Switch down, needle deflection, left.

Problem

Analogy between direct current and water flow.

Principle

Current always flows in the same direction from the positive to the negative terminal

Commercially, direct current is generated by a machine called a dynamo or generator, the wire on the armature passing in a magnetic flux, generating current in the armature which is brought out in one direction through the brushes on the commutator.

Object

To show the characteristics of direct current.

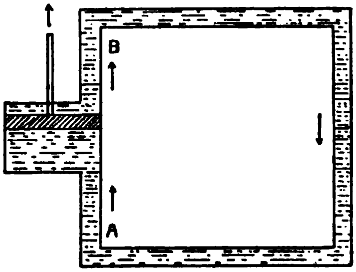
Questions

Where is direct current used to advantage?

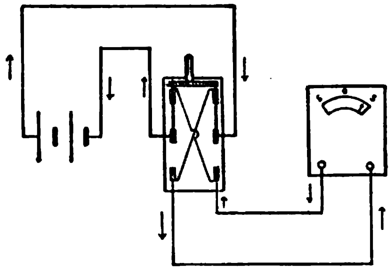
Is battery current direct or alternating?

What is meant by the positive terminal, negative terminal?

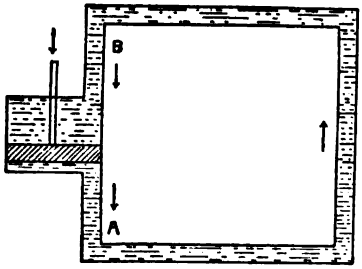
PROBLEM 17



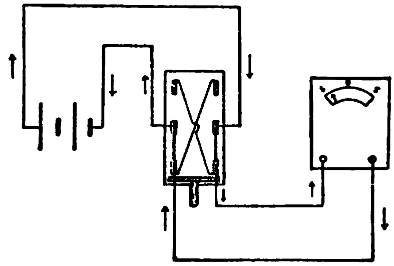
Piston up, flow toward B.



Switch up, needle deflection, right.



Piston down, flow toward A.



Switch down, needle deflection, left.

Problem

Analogy between alternating current and water flow.

Principle

Alternating current continually reverses its direction of flow with regular periodicity from zero to positive maximum, back to zero, then to negative maximum and back to zero; this rising and falling above and below zero is called alternation, two alternations constituting a cycle. The number of cycles per second is called frequency.

Commercially, alternating current is generated by a machine called a generator or alternator, the wire on the armature passing first in front of a north magnetic field pole, causing the current to flow in one direction, and then in front of a south magnetic field pole, causing the current to flow in the opposite direction. The current is thus brought out thru the brushes on the collector rings.

Object

To show the characteristics of alternating current.

Questions

What is the difference between direct and alternating current?

Where is alternating current used to advantage?

What is meant by alternation, cycle and frequency?

PROBLEM 18

Problem

Application of Ohm's Law.

Principle

$$C \text{ or } I = \frac{E}{R} \text{ or } \frac{W}{E}$$

$$R = \frac{E}{I} \text{ or } \frac{W}{I^2} \text{ or } \frac{E^2}{W}$$

$$E = I \times R \text{ or } \frac{W}{I}$$

$$W = E \times I \text{ or } I^2 \times R \text{ or } \frac{E^2}{R}$$

E = Volt, or unit of pressure.
C or I = Amperes, or unit of current.
R = Ohms, or unit of resistance.
W or P = Watt, or unit of power.
1 HP. = 1 Horse-power or 746 watts.
1 K. W.= 1 Kilowatt or 1,000 watts.

1. When any number of like or unlike resistances are connected in series, the total resistance is the sum of the various resistances.

2. To find the voltage drop or fall of potential of any inserted resistance, or part of line in the circuit, multiply the number of amperes flowing through that resistance by the number of ohms in that part.

3. The sum of the voltage drops will equal the voltage applied to the circuit.

4. To find the joint resistance, when like resistances are in multiple or parallel, divide the resistance of one path by the number of paths.

5. To find the joint resistance, when unlike resistances are connected in multiple, add the conductivity of the individual resistances and invert the sum.

6. To find the amount of current flowing thru any individual coil, when resistances are connected in multiple, divide the voltage drop across the joint resistance by the resistance of each individual coil.

7. The sum of the currents passing through the different coils, when connected in multiple, must always equal the current flowing through the entire circuit.

Object

To show the importance of a thoro understanding of the laws governing current, voltage, resistance, and watts.

Questions

1. What is the total resistance of 5-ohm, 10-ohm, and 15-ohm coils connected in series?

2. What is the voltage drop across the 10-ohm coil, if 5 amperes were flowing thru it? (Refer to Question 1.)

3. What voltage is necessary to force 5 amperes thru the three resistance coils in question 1?

4. What is the joint resistance of two 10-ohm coils connected in multiple?

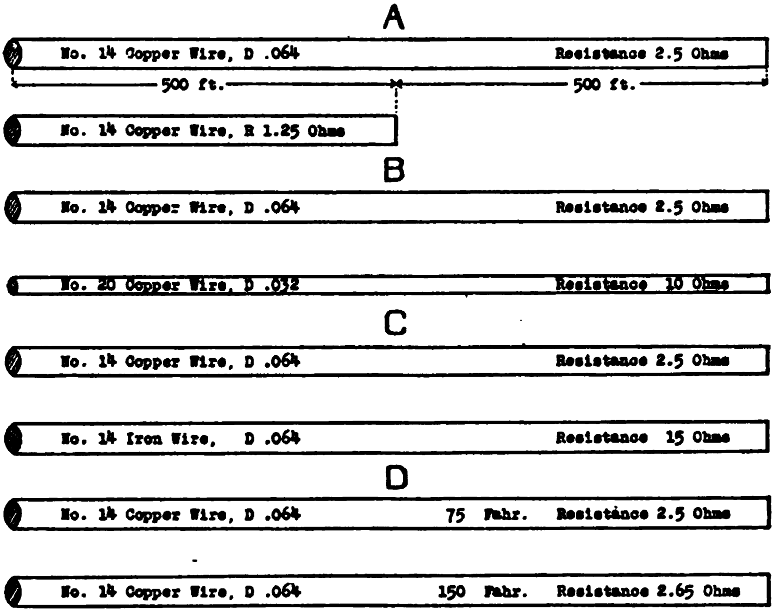
5. What is the joint resistance of the three coils in Question 1, if they were connected in multiple?

6. How much current would flow thru the 5-ohm coil only, in Question 5, if 10 volts are applied to the circuit?

7. How much current would flow thru the three coils in Question 5, if 10 volts are applied to the circuit?

8. How many watts are being consumed in a circuit carrying six amperes, at 110 volts pressure?

PROBLEM 19



Problem

Resistance *via* conductivity.

Principle

Resistance of a conductor is directly proportional to its length. Any substance will have twice the resistance and one-half the conductivity if its length be doubled, as in A.

Resistance of a conductor is inversely proportional to its cross-sectional area, and, in case of round wire, inversely proportional to the square of its diameter. Any substance will have twice the conductivity and one-half the resistance if its cross-sectional area is doubled, or one-quarter the resistance and four times the conductivity if the diameter is doubled, as in B.

Resistance of a conductor depends upon the material of which it is made, as in C.

Resistance of a metallic conductor increases as its temperature rises, at one-quarter of one per cent for every degree Fahrenheit, as in D. On the other hand, the resistance of carbon and electrolytes (battery solutions) decreases as the temperature rises.

Resistance is the opposition offered by any substance to the flow of an electric current through it.

Conductivity is the ability of the substance to conduct electricity. No conducting body possesses perfect conductivity but every conductor offers some resistance to the passage of current.

Conductor is a substance in which the opposition is small and the conductivity is good (good conductor). Good conductors are: silver, copper, aluminum, zinc, brass, platinum, iron, tin, lead, German silver and mercury.

Insulator is that substance which opposes the flow of current. A good insulator confines the current to the conductor.

Non-conductors are: dry air, glass, paraffin, amber, mica, shellac, resin, sealing wax, silk, dry paper, porcelain, oils, and slate.

Resistance is the reciprocal of conductivity. The greater the conductivity of a body the less its resistance. Place 1 over the number of ohms you are taking the reciprocal of and the result is the conductivity.

Object

To show that the resistance and conductivity vary according to the length, area, and kind of material used.

Questions

What is the resistance of 4,000 ft. of No. 14 copper wire, if 1,000 ft. has 2.5 ohms resistance?

What is the resistance of 1,000 ft. of No. 8 copper wire, diameter .128, if 1,000 ft. of copper wire, diameter .064, is 2.5 ohms?

If the resistance of iron wire is about six times that of copper of the same size, what is the resistance of 2,000 ft. No. 14 iron wire if 1,000 ft. No. 14 copper wire has 2.5 ohms resistance?

What is the resistance of 1,000 ft. of No. 14 copper wire, at 100° Fahr., if it has 2.5 ohms resistance at 75° Fahr.?

PROBLEM 20

Problem

Wire calculations.

Principle

The resistance of a conductor is directly proportional to its length, inversely proportional to its cross-section and depends upon the nature of the material used.

The resistance of copper wire is:

$$R = \frac{K \times L}{CM}$$

L = Length of wire in feet.

CM = Circular mils or D^2 (diameter in mils squared).

K = Constant 10.7 and is the resistance per mil foot of copper wire at 75° Fahr.

K varies, according to the kind of wire used, as follows:

$$K = \begin{cases} \text{Silver} & 9.7 \\ \text{Aluminum} & 19 \\ \text{Platinum} & 58.8 \\ \text{Iron} & 63 \\ \text{German Silver} & 135.9 \end{cases}$$

$$\text{Resistance of conductor} = \frac{\text{volts lost}}{\text{current in amperes}}$$

Then the above formula becomes:

(a) $$\text{Circular mils} = \frac{10.7 \times \text{feet} \times 2 \times \text{amperes}}{\text{volts lost}}$$

(b) $$\text{Volts lost} = \frac{10.7 \times \text{feet} \times 2 \times \text{amperes}}{\text{circular mils}}$$

(c) $$\text{Amperes} = \frac{\text{circular mils} \times \text{volts lost}}{\text{feet} \times 2 \times 10.7}$$

NOTE—Refer to page 70 (General Principles Involved in Electric Light Construction) for size, area, and carrying capacity of wires.

Object

To show how to calculate the proper size of wire to give a certain voltage drop for a corresponding current.

To calculate the volts lost for a given size of wire and number of amperes flowing.

To calculate the current which will produce a given voltage drop in a certain size of wire.

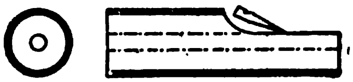
Questions

Find the size of wire necessary to carry 25 amperes 500 ft. from the source with only 16-volt drop.

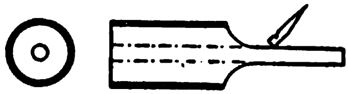
Find the voltage loss, having given a transmission distance of 350 ft., using No. 4 wire and a current of 50 amperes.

Find the current in amperes which a No. 10 wire will carry over a 100-ft. circuit, with a 25-volt loss.

PROBLEM 21



Skinning



Scraping

Problem

Preparing wires for a Western Union splice.

Principles

Avoid nicking wire; have wire thoroly clean.

Object

Connection must be mechanically and electrically secure.

Operations

Removing insulation; scraping wire.

Tools

Knife.

Material

Pieces of insulated wire.

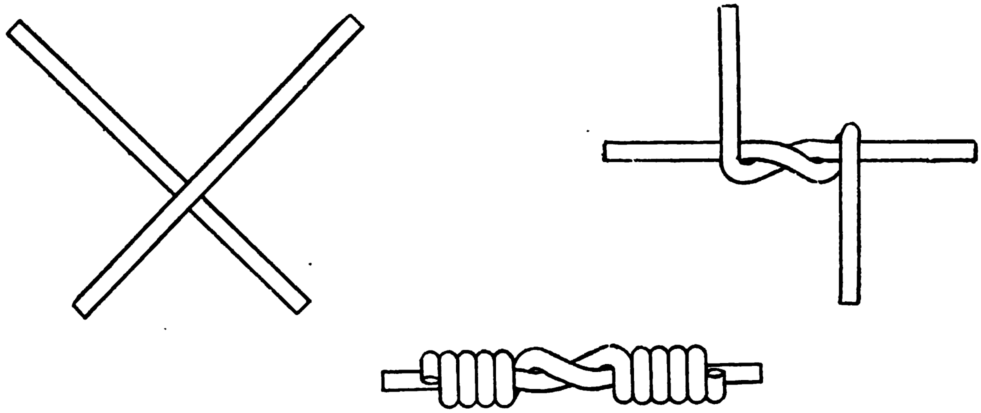
Questions

Why should you hold the knife at this angle?

When making a splice with a nicked wire, what is likely to occur?

When scraping, why should you not use the front edge of the knife blade?

PROBLEM 22



Problem

Making a Western Union splice.

Principle

Wind wire tightly and evenly.

Object

Connection must be mechanically and electrically secure.

Operation

Splicing wires.

Tools

Pair of pliers.

Material

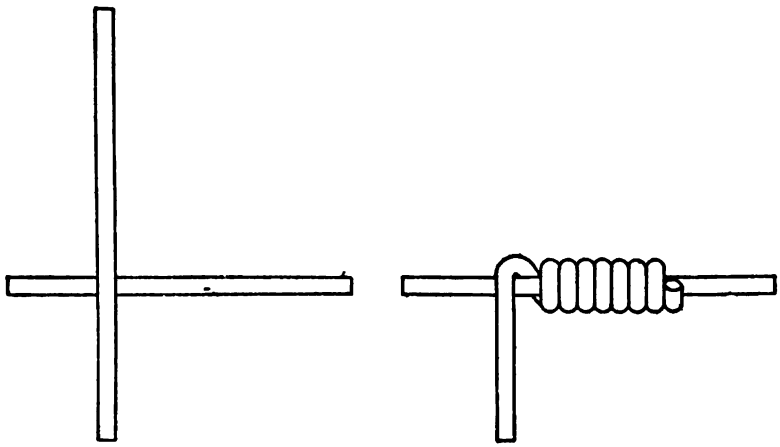
Wire.

Questions

Why should the wire be wound tightly and evenly?

What trouble is likely to occur from a poorly made splice?

PROBLEM 23



Problem

Making a branch tap.

Principles

Avoid nicking wire; have wire thoroly clean; wind wire tightly and evenly.

Object

Connection must be mechanically and electrically secure.

Operations

Tools

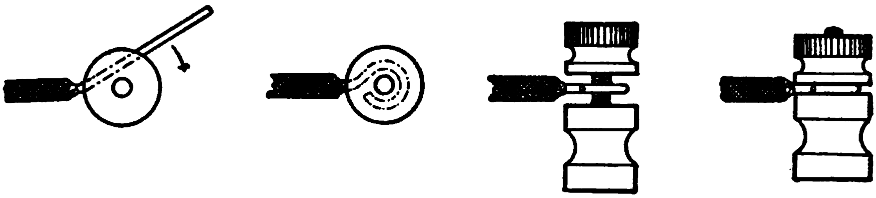
Material

Questions

Why should the end of the coiled wire be pinched tightly against the tapped wire?

How would you make a double-branch tap? (See fore-notes.)

PROBLEM 24



Problem

Fastening wire to binding post.

Principle

Bend wire around screw in clockwise direction.

Object

To have wire securely fastened when screw is tightened.

Operations

Fastening wire.

Tools

Material

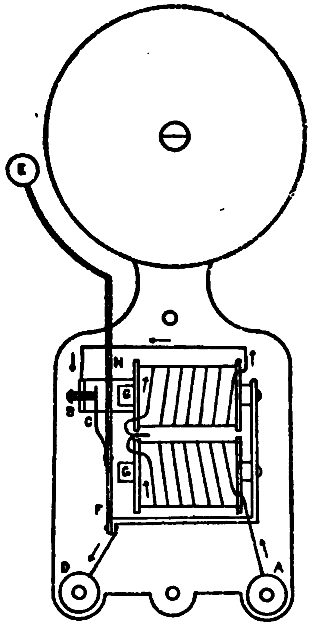
Electric bell or other apparatus.

Questions

Why should wire pass around in a clockwise direction?

Why should wire not have more than one turn?

PROBLEM 25



A Binding post
B Adjusting screw
C Contact spring
D Binding post
E Hammer
F Armature spring
G Cores
H Armature

Problem
Electric bell.

Principle
Application of electro-magnetism.

Object
To show the current's path and effect.

Tools

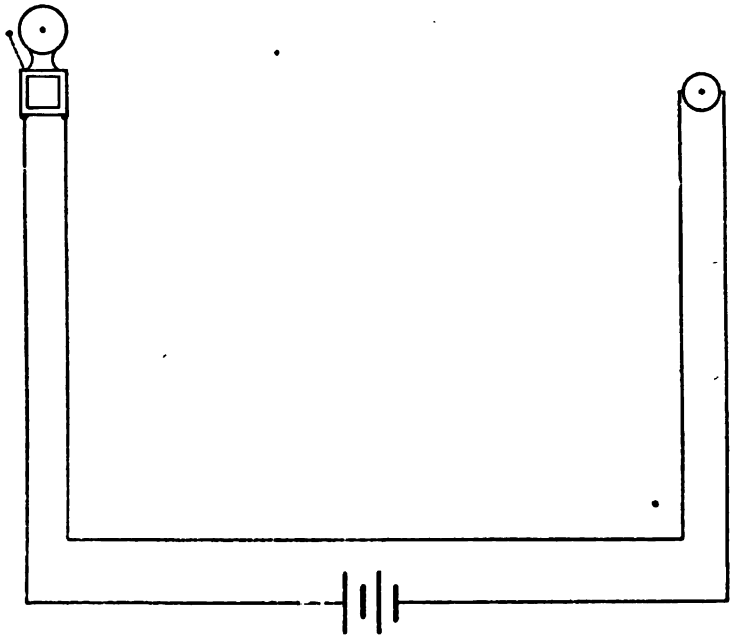
Material

Questions
Explain how an electric bell operates?

How would you adjust an electric bell?

How would you change a vibrating bell to a single-stroke? (See fore-notes.)

PROBLEM 26



Problem

Connections for simple bell circuit.

Principle

Button must complete circuit from battery to bell.

Object

To ring bell properly.

Operations

Fastening, skinning, scraping and connecting.

Tools

Screw-driver, knife, pliers and hammer.

Material

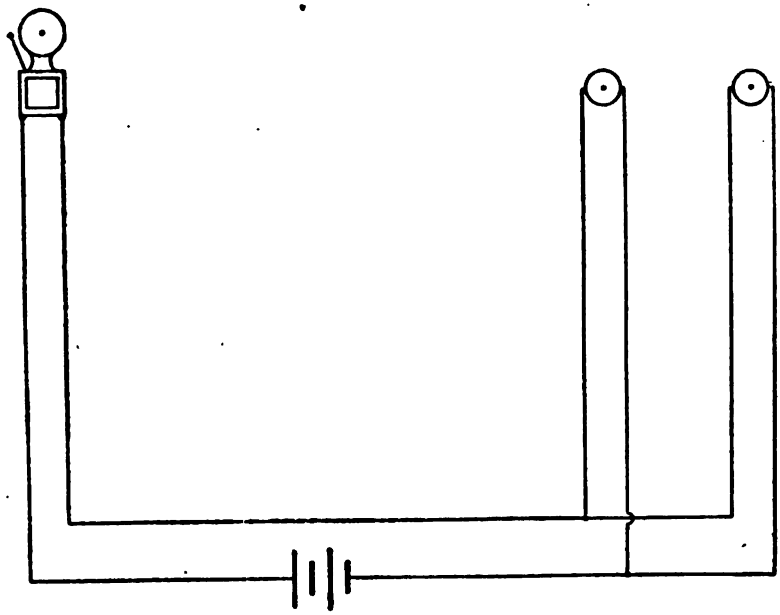
Electric bell, push button, two dry cells, No. 18 bell wire, staples, and 1" No. 6 round-head wood screws.

Questions

What would happen if the wires running to the push-button became crossed?

What would happen if the wires running to the battery became crossed?

PROBLEM 27



Problem

Connections for two push-buttons to ring one bell.

Principle

Either button must complete the circuit.

Object

To show that more than one button can be used.

Operations

Tools

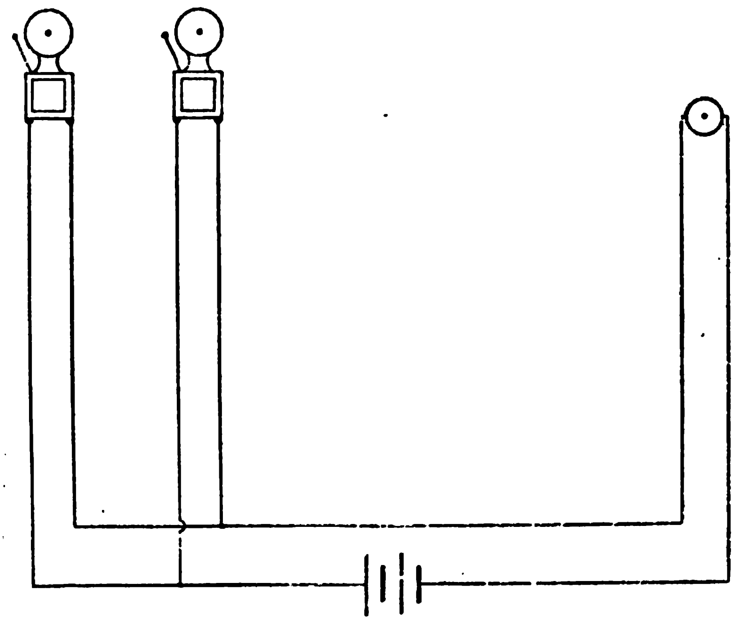
Material

Questions

What would happen if both buttons were pressed at the same time?

If the bell did not ring from either button, where would you look for the trouble?

PROBLEM 28



Problem

Connection for one push-button to ring two bells.

Principle

Vibrating bells must be in parallel in order to work satisfactorily.

Object

To have two or more bells ring at the same time.

Operations

Tools

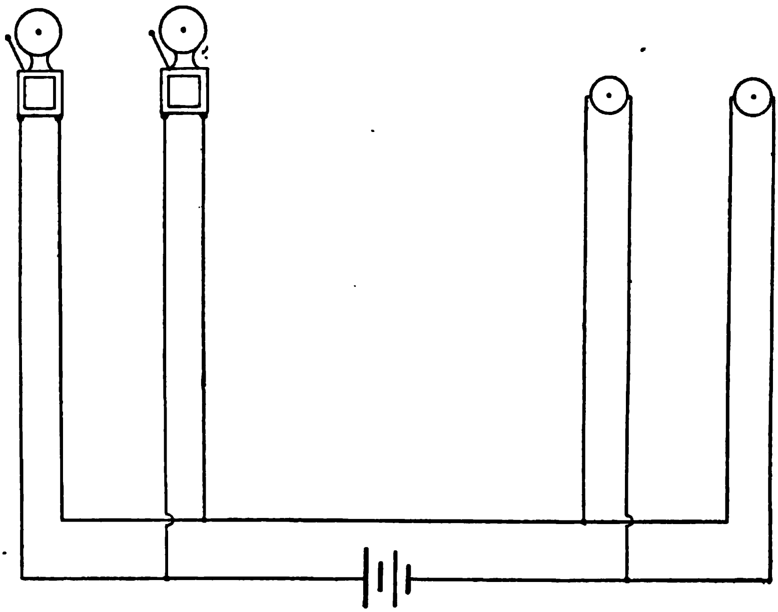
Material

Questions

What is meant by parallel connection?

If a wire became disconnected at one bell, would it effect the ringing of the other?

PROBLEM 29



Problem

Connections for two push-buttons to ring two bells.

Principle

Either button must complete the circuit to both bells.

Object

To show that you can combine various problems into one.

Operations

Tools

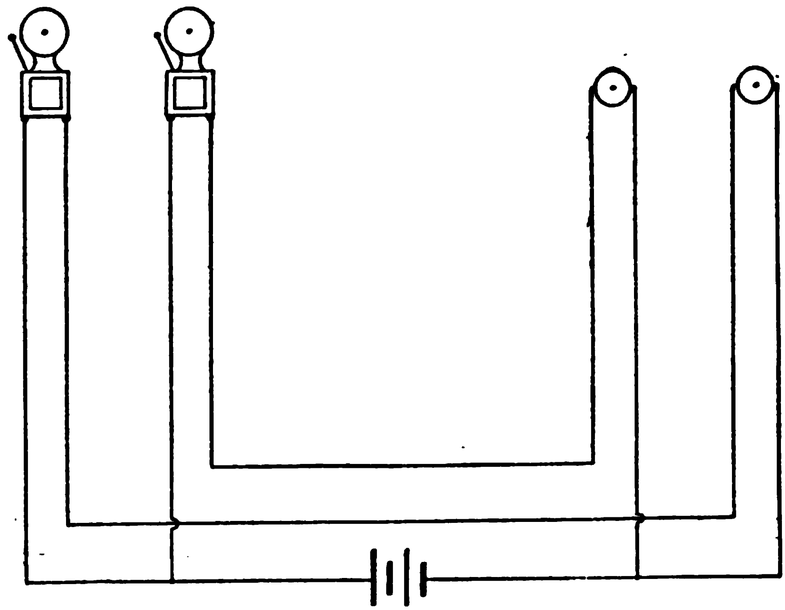
Material

Questions

What two problems are combined in this lesson?

If only one bell rang, where would you look for the trouble?

PROBLEM 30



Problem

Connections for two or more push-buttons to ring separately two or more bells.

Principle

One wire must be used for a common return to bells or buttons.

Object

To save wire by having the current to two or more bells or buttons, pass thru one wire.

Operations

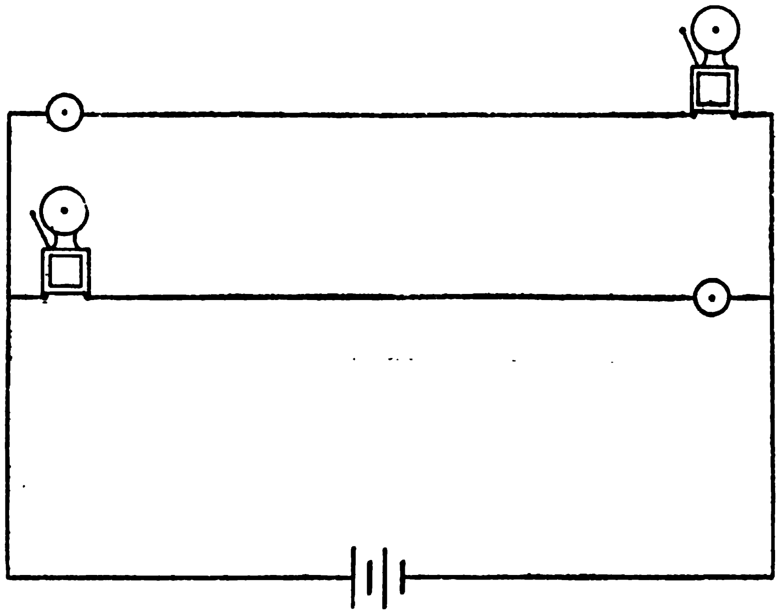
Tools

Material

Questions

If you add ten bells and buttons to this circuit (a) would you strengthen the battery in proportion? (b) would you increase the size of wire in proportion?

PROBLEM 31



Problem

Connections for three-wire return call system.

Principle

One wire must be used for a common return to bells and buttons.

Object

To receive and answer a call.

Operations

Tools

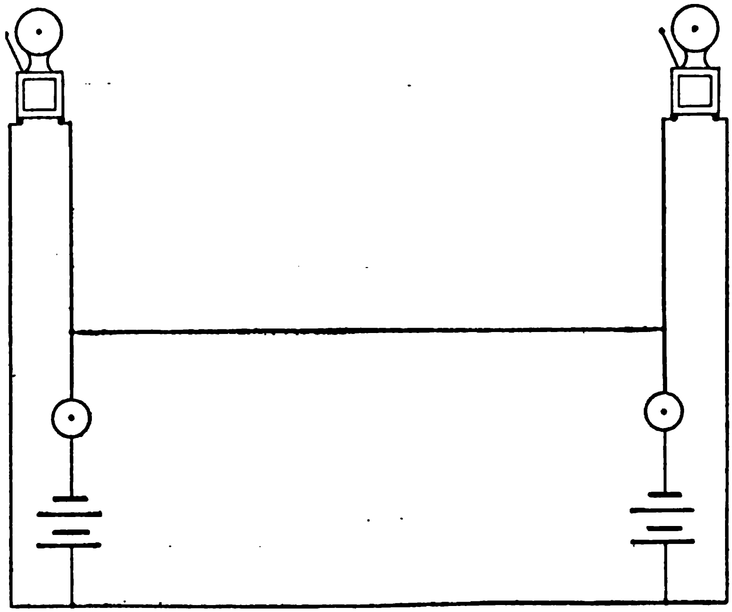
Material

Questions

If wire connecting the lower bell and button becomes broken, would it affect the ringing of the other?

About what distance would this circuit work on two dry cells, using No. 18 bell wire?

PROBLEM 32



Problem

Connections for two-wire return call system.

Principle

Two sets of batteries must be used.

Object

To save wire by using two sets of batteries.

Operations

Tools

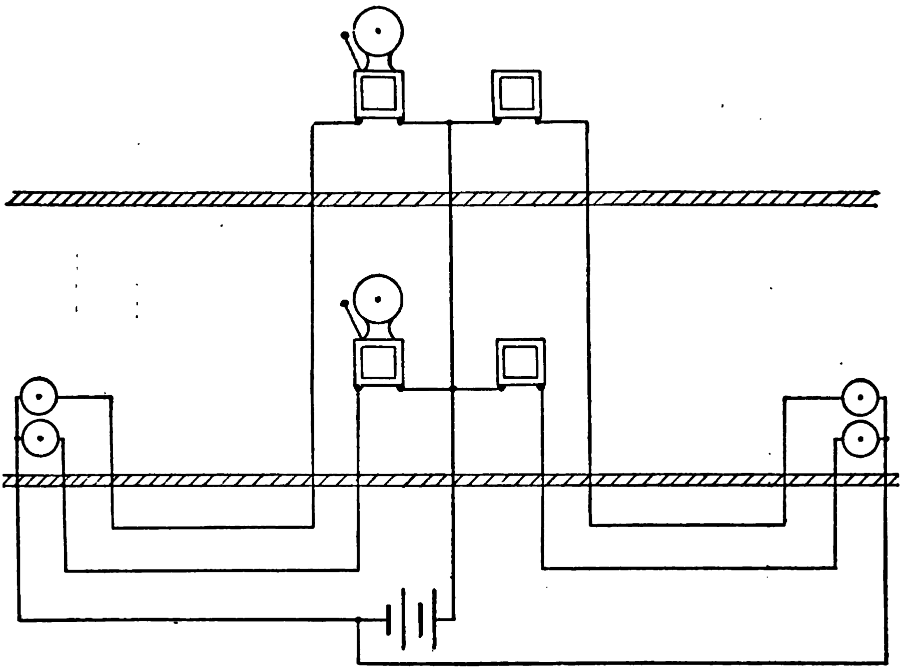
Material

Questions

Are both sets of batteries supplying current when one button is pressed?

Do both bells ring when one button is pressed? (See fore-notes)

PROBLEM 33



Problem

Connections for bell wiring for two-family house.

Principle

Buzzers must ring from back door button.

Object

To show relative location of bells, buzzers, buttons, and battery.

Operations

Boring.

Tools

Brace and 18 inch 5/16" Syracuse wood bit.

Material

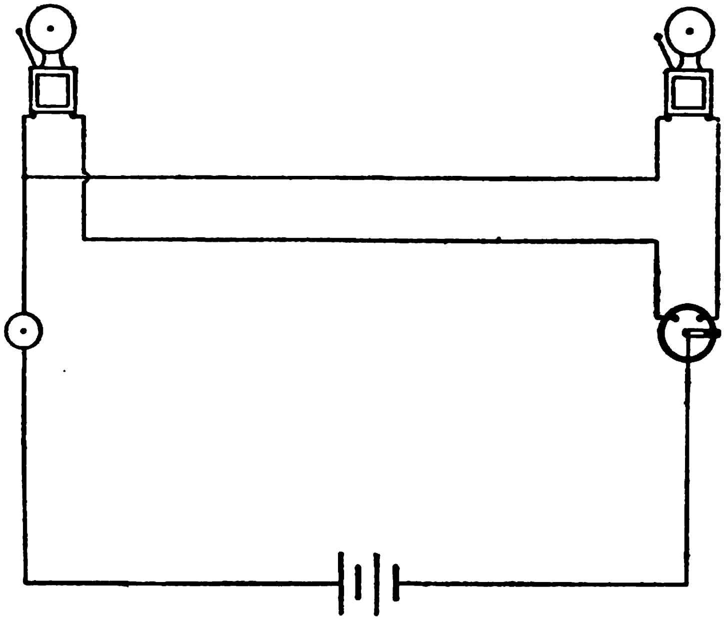
Two buzzers.

Questions

Why is it important that you do not put two wires under one staple?

Why should wires not be run so that they would be imbedded in plaster?

PROBLEM 34



Problem

Connections for ringing bells separately from one push-button.

Principle

Switch must select bell to be rung.

Object

To show that any number of bells may be rung selectively from one push-button.

Operations

Tools

Material

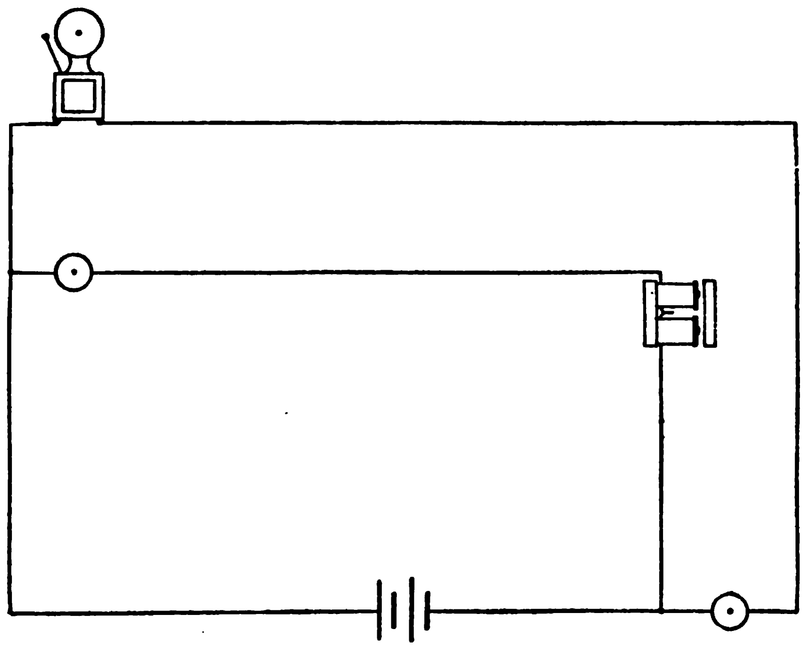
Two-point battery switch.

Questions

Why is this system used in a doctor's residence?

What would be the result if wire became disconnected at switch lever?

PROBLEM 35



Problem

Connections for an electric door-opener.

Principle

Electro magnets must release the latch and the spring must push door open.

Object

To show how a door may be opened by electricity.

Operations

Cutting.

Tools

Wood chisel.

Material

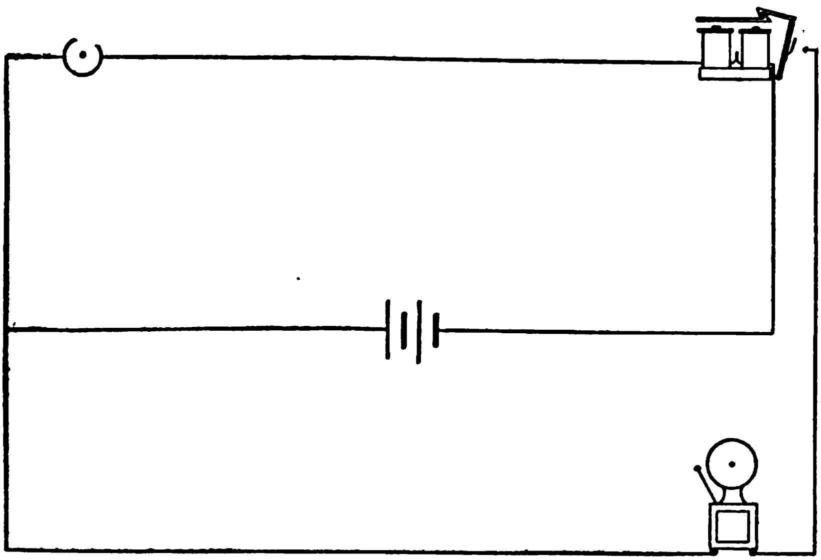
One electric door opener.

Questions

Can the door-opener be operated from more than one place?

On what principle does the electric door opener work?

PROBLEM 36



Problem

Connections for automatic drop.

Principle

Bell must ring until attachment is replaced.

Object

To show how a constant ringing attachment may be used.

Operations

Tools

Material

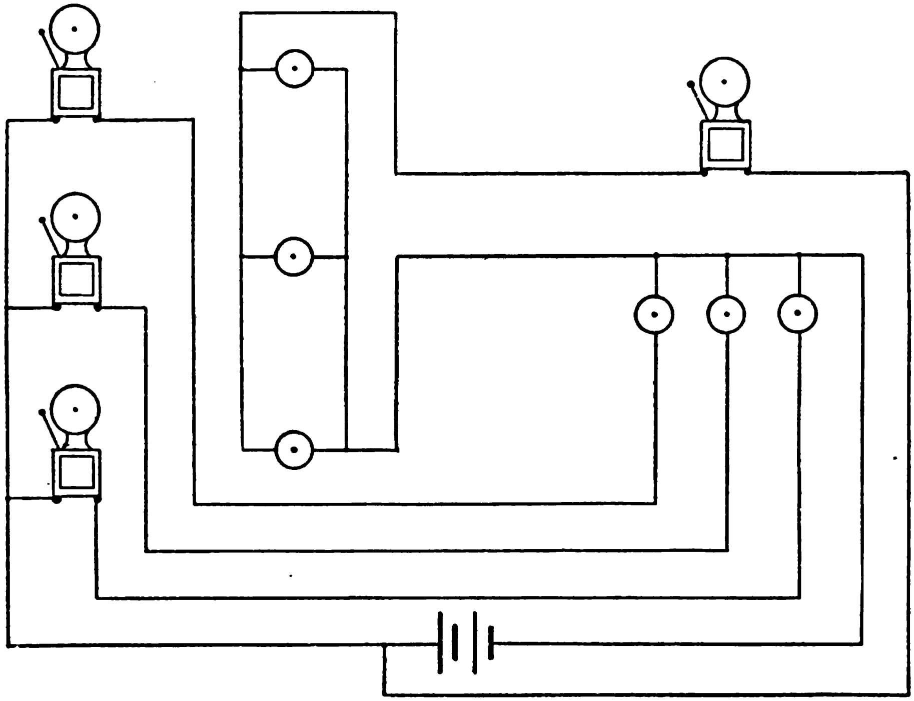
Automatic drop.

Questions

Could you replace the attachment if the button became short-circuited?

Where could this system be used to advantage?

PROBLEM 37



Problem

Connections for return call system, using three push-buttons for selecting bells, and answering back buttons.

Principle

Each button must complete the circuit to its own bell.

Object

To show that more than two stations can be used on a return call system.

Operations

Tools

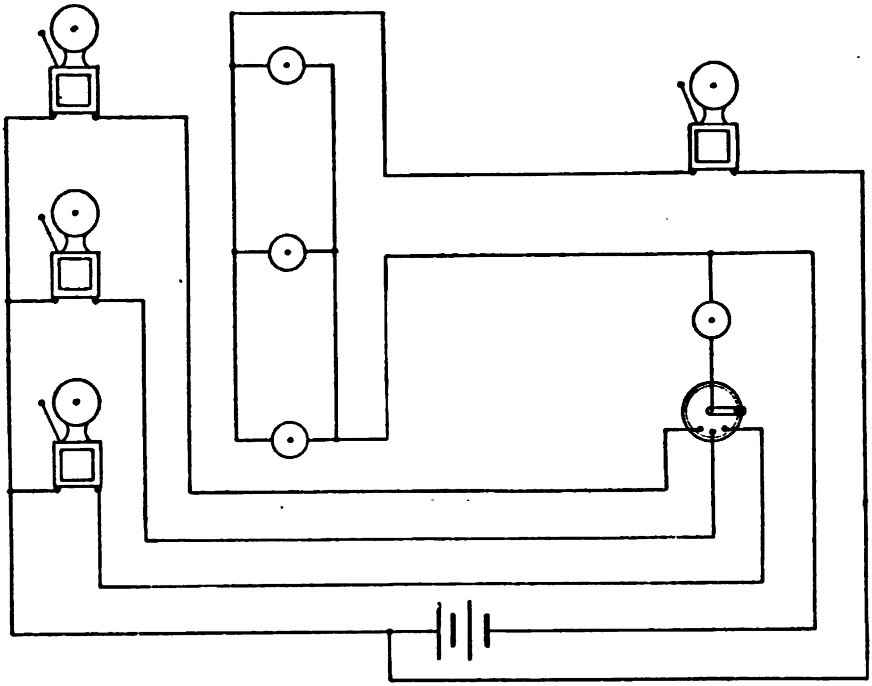
Material

Questions

How would you change the connections to save one wire?

How many buttons and bells would be required for a five-station system? (See fore-note)

PROBLEM 38



Problem

Connections for return call system using one push-button in connection with three point switch, and answering back buttons.

Principle

Switch must select bell to be rung.

Object

To show that a large number of stations can be used on a return call system.

Operations

Tools

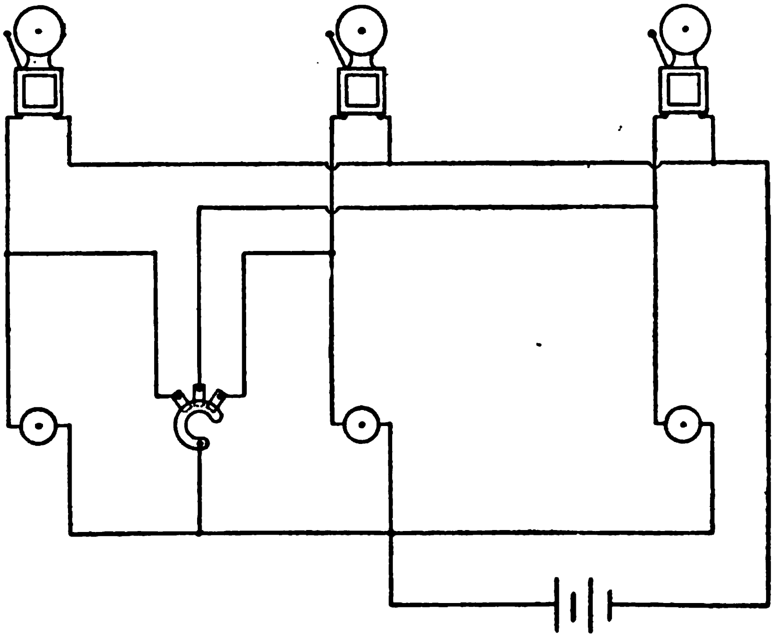
Material

Questions

What advantage has this system over the system in Problem No. 37?

Does this system require a smaller or greater number of wires than the system in Problem 37? (See fore-notes)

PROBLEM 39



Problem

Connections for ringing bells separately and simultaneously.

Principle

Wires and springs must be kept separate at master push-button.

Object

To show the use of a four-point push-button.

Operations

Tools

Material

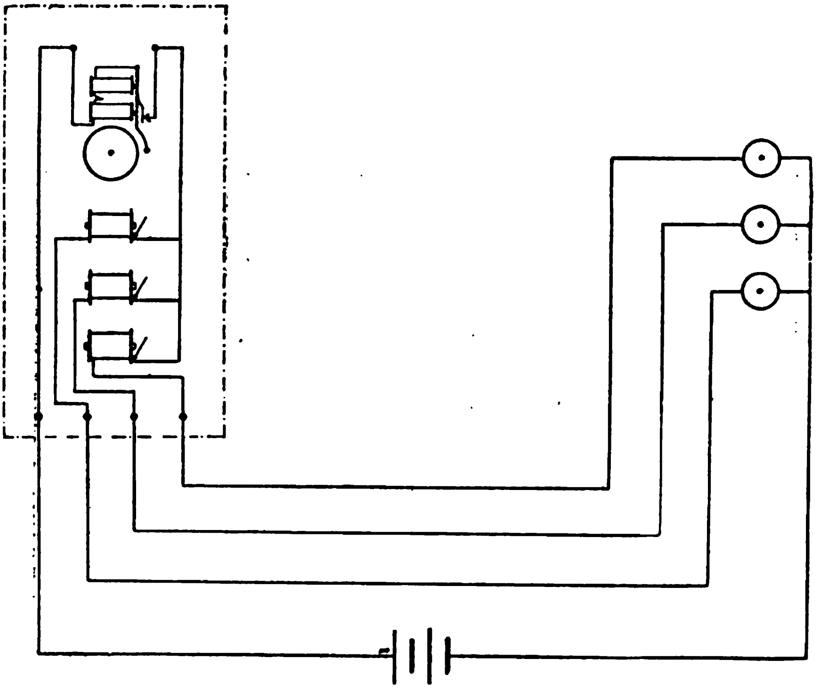
One four-point push-button.

Questions

To what spring should the battery wire be connected? Why?

If two of the small springs on the master button became crossed, what effect would it have on the system?

PROBLEM 40



Problem

Connections for three-point mechanical reset annunciator.

Principle

The annunciator must indicate the call.

Object

To show the inside connections of an annunciator.

Operations

Tools

Material

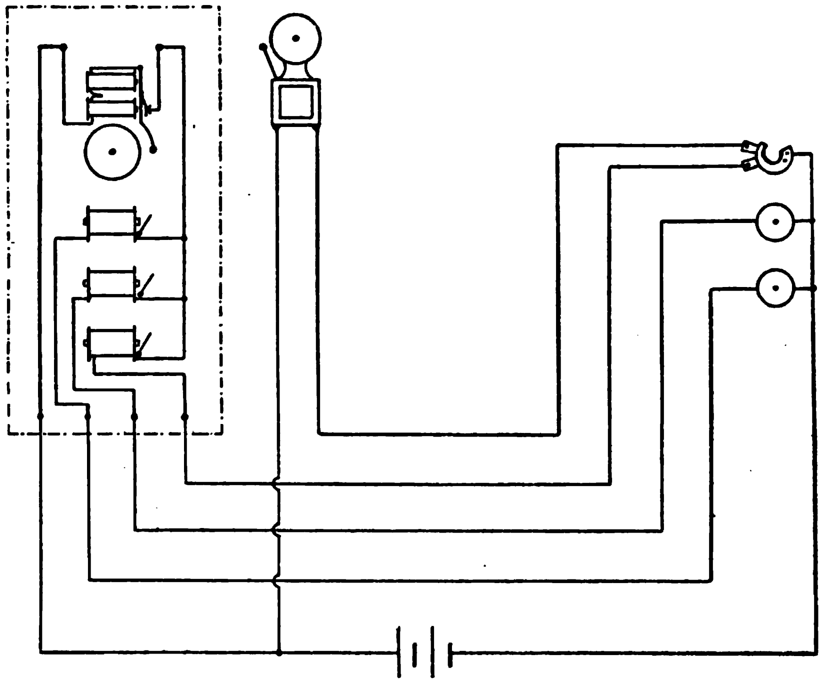
One three-point mechanical reset annunciator.

Questions

If one of the indicating coils became open-circuited, what effect would it have on the system?

If one of the magnet coils of the bell became open-circuited, what effect would it have on the system? (See fore-notes)

PROBLEM 41



Problem

Connections for an extension bell on an annunciator system.

Principle

Extension bell must ring from one button only.

Object

To show one method of using three-point button.

Operations

Tools

Material

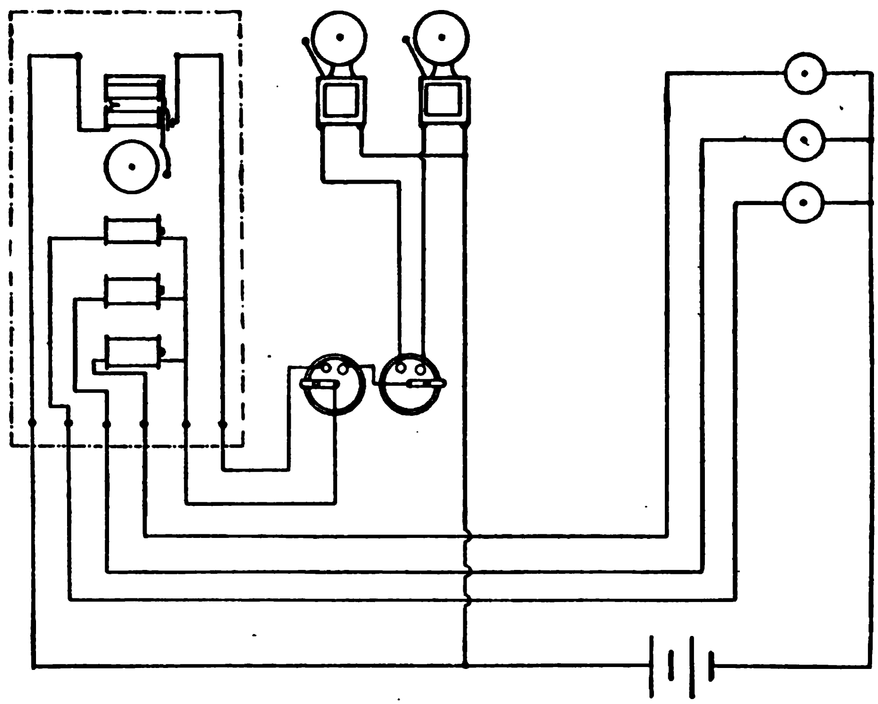
One three-point push-button.

Questions

Why is it necessary to use a three-point push-button?

How would you connect the extension bell if it were single-stroke? (See fore-notes)

PROBLEM 42



Problem

Connections for selective extension bells on an annunciator system.

Principle

Switches must be employed to select the bells.

Object

To show how a number of extension bells may be connected to an annunciator system.

Operations

Tools

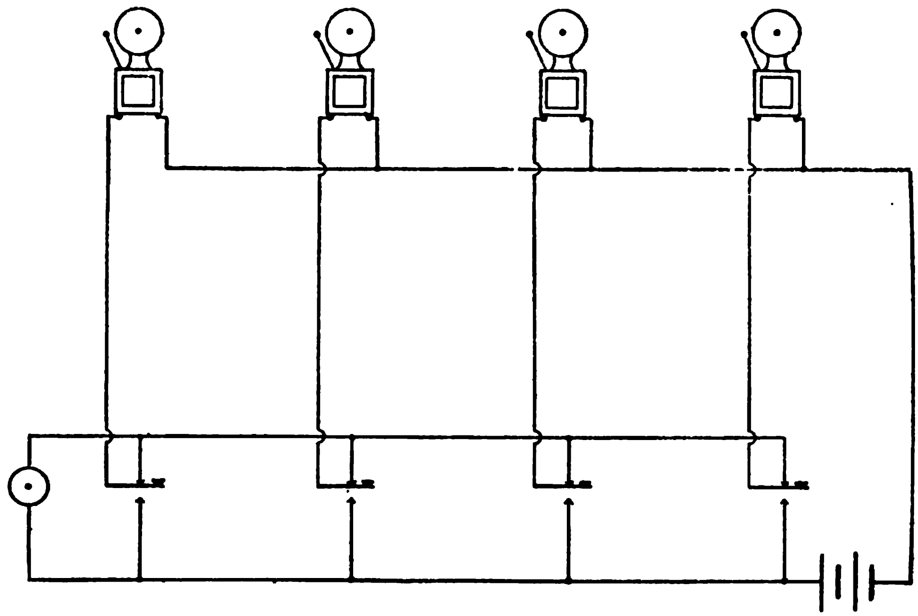
Material

Questions

Does the annunciator bell ring with either of the extension bells?

Could the extension bells be controlled by one switch? (See fore-notes)

PROBLEM 43



Problem

Connections for ringing bells separately and simultaneously.

Principle

The main and back springs must be in contact.

Object

To show the method of using a three-point back-contact push-button.

Operations

Tools

Material

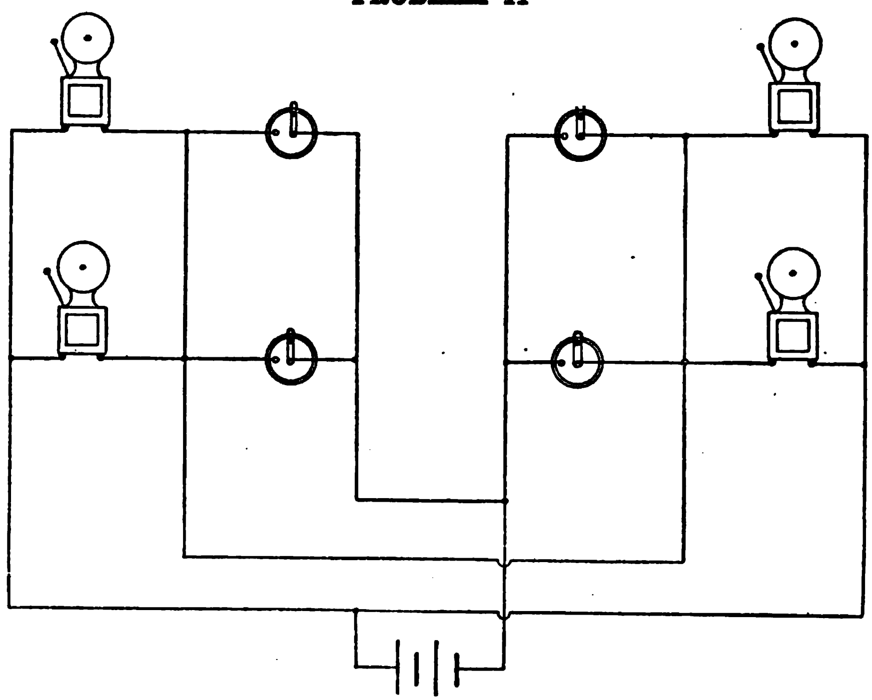
Three three-point back-contact push-buttons.

Questions

If the main and back springs of one button were not in contact, what effect would it have on the system?

What advantage would this system have over the system in Problem 39, where a large number of stations is required? (See fore-notes)

PROBLEM 44



Problem

Connections for fire-alarm system.

Principle

Bell must ring continuously when glass is broken or switch is turned on.

Object

To show connections for simple fire-alarm system.

Operations

Tools

Material

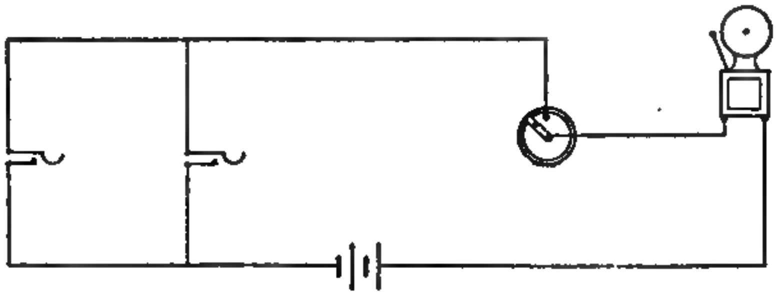
Four single-pole switches or fire alarm boxes.

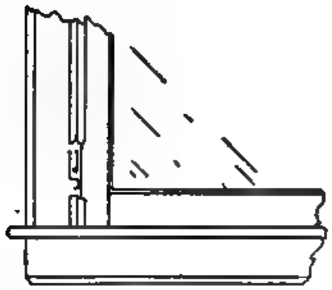
Questions

If a bell and switch constitute a station, how many wires run between them?

If a wire became disconnected at (a) bell, and at (b) switch point, what effect would it have on the system?

PROBLEM 45





Problem

Connections for open-circuit burglar-alarm system.

Principle

The bell must ring as long as the door or window is open.

Object

To show the connections and position of springs with window open and closed.

Operations

Tools

Material

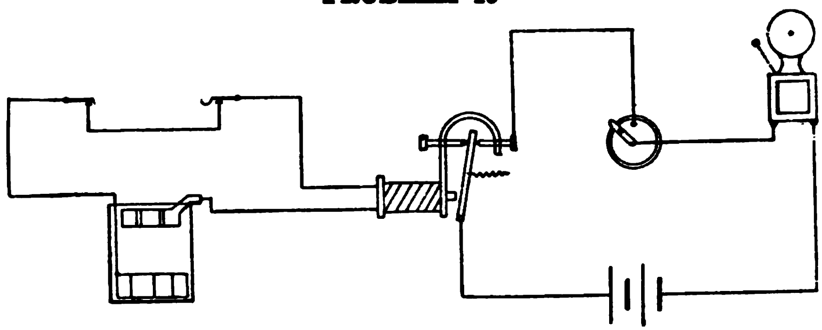
Burglar-alarm attachments (door and window springs).

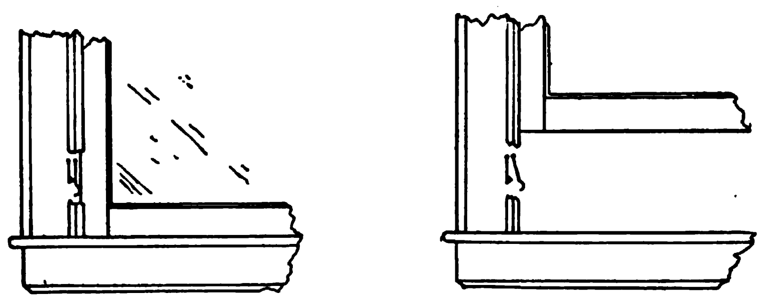
Questions

Why is the switch put in the circuit?

How are the door and window attachments connected—in series or multiple?

PROBLEM 46





Problem
Connections for closed-circuit burglar-alarm system.

Principle
The circuit of the relay magnets must be open to ring the bell.

Object
To show the use of a gravity cell and circuit—closing relay.

Operations
Charging cell and adjusting relay.

Tools

Material
Gravity cells, circuit-closing relay.

Questions
Explain the operations from the opening of the window to the ringing of the bell?

Why is it necessary to use gravity cells?

How are the door and window attachments connected—in series or multiple?

GENERAL PRINCIPLES TO OBSERVE IN ELECTRIC LIGHT CONSTRUCTION.

Wires

Must not be of smaller size than No. 14 B & S gauge, except as allowed for fixture work and pendant cord.

Must be so spliced or joined as to be both mechanically and electrically secure without soldering. The joint must then be soldered unless made with some form of approved splicing device, and covered with an insulation equal to that on the conductors.

Stranded wires (except in flexible cords) must be soldered before being fastened under clamps or binding screws, and, whether stranded or solid, when they have a conductivity greater than that of No. 8 B & S gauge, they must be soldered into lugs for all terminal connections.

Must be separated from contact with walls, floors, timber, or partitions thru which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain, except at outlets where approved flexible tubing is required.

Must not come nearer than two inches to any other electric lighting, power, or signaling wire, without being permanently separated there from by some continuous and firmly-fixed non-conductor.

Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally.

The installation of electrical conductors in wood molding, or on insulators in elevator shafts will not be approved, but conductors may be installed in such shaft if encased in approved metal conduits, or armored cables.

Must, where exposed to mechanical injury, be suitably protected. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be installed in approved conduit or armored cable or be attached by their insulating supports to the under side of a wooden strip, not less than one-half inch in thickness, and not less than three inches in width. Instead of the running boards, guard strips on each side of and close to the wires will be accepted. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Protection on side walls must extend not less than five feet from the floor and must consist of substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) or approved metal conduit or pipe of equivalent strength.

Must not be "dead-ended" at a rosette socket or receptacle unless the last support is within twelve inches of the same.

Rigid supporting requires, under ordinary conditions, where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports must be shortened. In buildings of mill construction, mains of not less than No. 8 B & S gauge, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

Table of Carrying Capacity of Wires

The following table, showing the allowable carrying capacity of copper wires and cables of ninety-eight per cent conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is eighty-four per cent of that given in the following tables for copper wire with the same kind of insulation.

B & S G	Rubber Insulation Amperes	Other Insulations Amperes	Circular Mils
18	3	5	1,624
16	6	10	2,583
14	15	20	4,107
12	20	25	6,530
10	25	30	10,380
8	35	50	16,510
6	50	70	26,250
5	55	80	33,100
4	70	90	41,740
3	80	100	52,630
2	90	125	66,370
1	100	150	83,690
0	125	200	105,500
00	150	225	133,100
000	175	275	167,800
0000	225	325	211,600
Circular Mils			
200,000	200	300	
300,000	275	400	
400,000	325	500	
500,000	400	600	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

Wires (For concealed knob-and-tube work)

Must have an approved rubber insulating covering.

Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Should preferably be run singly on separate timbers, or studding and must be kept at least five inches apart.

Must be separated from contact with the walls, floor timbers, and partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain. Wires passing through cross timbers in plastered partitions must be protected by an additional tube extending at least four inches above the timber.

At distribution centers, outlets or switches where space is limited and the five-inch separation cannot be maintained, each wire must be separately encased in a continuous length of approved flexible tubing.

Must at all outlets be protected by approved flexible tubing extending in continuous lengths from the last procelain support to at least one inch beyond the outlet. In the case of combination fixtures a tube must be extended at least flush with the outer end of the gas cap.

Wires (For fixture work)

Must not be smaller than No. 18 B & S gauge and must have an approved rubber insulation.

Wires of different systems must never be contained in, or attached to, the same fixture, and under no circumstances must there be a difference of potential of more than 300 volts between wires contained in, or attached to, the same fixture.

Wires (Flexible cord)

Must not be used as a support for clusters.

Must not be used except for pendants, wiring of fixtures, portable lamps or motors, and portable heating apparatus.

For all portable work, including those pendants which are liable to be moved about sufficiently to come in contact with surrounding objects, flexible wires and cables especially designed to withstand this severe service must be used.

Must not be used in show windows or show cases except when provided with an approved metal armor.

Must be protected by insulating bushings where the cord enters the socket.

Must be so suspended that the entire weight of the socket and lamp will be borne by some approved method under the bushing in the socket, and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

Wires (For wood and metal molding)

Must have an approved rubber insulating covering, and must be in continuous lengths from outlet to outlet, or from fitting to fitting, no joints or taps to be made in molding. Where branch taps are necessary in molding work approved fittings for this purpose must be used.

Must never be placed in either wood or metal molding in damp locations, concealed locations, or where the difference of potential between any two wires in the same system is over 300 volts.

Must for alternating current systems, if in metal molding, have the two or more wires of the circuit installed in the same molding.

Wires (For conduit and armored cable work)

Must have an approved rubber insulating covering and must within the metal tubing be without splice or tap.

Must not be drawn in until all mechanical work on the building has been, as far as possible, completed.

Conduit (Installation of)

No conduit smaller than one-half inch electrical trade shall be used.

The radius of the curve of the inner edge of any elbow is not to be less than three and one-half inches. Must not have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlet not being counted.

Must be continuous from outlet to outlet or to junction boxes or cabinets, and the conduits must properly enter, and be secured to all fittings and the entire system must be mechanically secured in position.

Junction boxes must always be installed in such a manner as to be accessable.

Conduits and gas pipes must be securely fastened in outlet boxes, junction boxes, and cabinets, so as to secure good electrical connections.

Fixtures (Installation of)

When supported at outlets in metal conduit, armored cable, or metal molding systems, or from gas piping or any grounded metal work, or when installed on metal walls or ceilings, or on plastered walls or ceilings containing metal lath, or on walls or ceilings in fireproof buildings, must be insulated from such supports by approved insulating joints placed as close as possible to the ceilings or walls. The insulating joints may be omitted in conduit, armored cable, or metal molding systems with straight electric fixtures in which the insulation of conductors is the equivalent of insulation in other parts of the system, and provided that approved sockets, recptacles, or wireless clusters are used of a type having porcelain or equivalent insulation between live metal parts and outer metal shells, if any.

Gas pipes must be protected above the insulating joint by approved insulating tubing, and where outlet tubes are used they must be of sufficient length to extend below the insulating joint, and must be so secured that they will not be pushed back when the canopy is put in place.

When insulating joints are required, fixture canopies of metal must be thoroly and permanently insulated from metal walls or ceilings, or from plaster walls or ceilings on metal lathing, and from outlet boxes.

Switches (Installation of)

Must be placed on all service wires, either overhead or underground, in the nearest readily accessible place, to the point where the wires enter the building, and arranged to cut off the entire current.

Must always be placed in dry, accessible places, and be grouped as far as possible. Single-throw knife switches must be so placed that gravity will not tend to close them. Double-throw knife switches may be mounted so that the throw will be either vertical or horizontal as preferred.

When practicable, switches must be so wired that the blades will be "dead" when the switch is open.

When switches are used in rooms where combustible flyings would be likely to accumulate around them, they must be enclosed in dust type cabinets.

Three-way switches are considered as single-pole switches.

When flush switches or receptacles are used, whether with conduit systems or not, they must be enclosed in an approved box constructed of iron or steel in addition to the porcelain enclosure of the switch or receptacle.

Sub-bases of non-combustible, non-absorptive insulating material, which will separate the wires at least one-half inch from the surface wired over, must be installed under all snap switches used in exposed knob and cleat work. Sub-bases must also be used in molding work, but they may be made of hard wood or they may be omitted if the switch is approved for mounting directly on the molding.

Single-pole switches must never be used as service switches nor for the control of outdoor signs, nor placed in the neutral wire of a three-wire system except in the two-wire branch or tap circuit supplying not more than 660 watts.

Armored Cable (Installation of)

All bends must be so made that the armor of the cable will not be injured. The radius of the curve of the inner edge of any bend not to be less than 1½ inches.

For alternating current systems, must have the two or more conductors of the circuit enclosed in one metal armor.

The armor of the cables and gas pipes must be securely fastened in outlet boxes, junction boxes, and cabinets, so as to secure good electrical connection.

Junction boxes must always be installed in such a manner as to be accessible.

Must be equipped at every outlet with an approved outlet box or plate, as required in conduit work.

Must have the metal armor of the cables permanently and effectually grounded to water piping, gas piping, or other suitable grounds, provided that when connections are made to gas piping, they must be on the street side of the meter. If the armored cable system consists of several separate sections, the sections must be bonded to each other and the system grounded, or each section may be separately grounded. This also applies to conduit and metal molding work.

Metal Molding (Installation of)

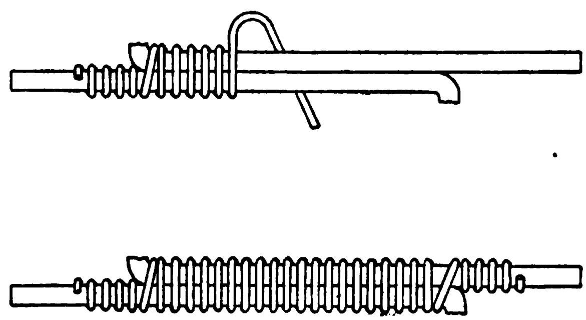
Must be continuous from outlet to outlet, to junction boxes, or approved fittings designed especially for use with metal moldings, and must at all outlets be provided with approved terminal fittings which will protect the insulation of conductors from abrasion, unless such protection is afforded by the construction of the boxes or fittings.

Such moldings where passing through a floor must be carried through an iron pipe extending from the ceiling below to a point five feet above the floor, which will serve as an additional mechanical protection and exclude the presence of moisture often prevalent in such locations.

Backing must be secured in position by screws or bolts, the heads of which must be flush with the metal.

Metal moldings and gas pipes must be securely fastened to outlet boxes, junction boxes and cabinets so as to secure a good electrical connection. Moldings must be so installed that adjacent lengths of moldings will be machanically and electrically secured at all points.

PROBLEM 47



Problem

Making a banded splice.

Principle

Wire must be thoroly clean; wire must be evenly and tightly wound.

Object

Connection must be mechanically and electrically secure before soldering.

Operations

Tools

Material

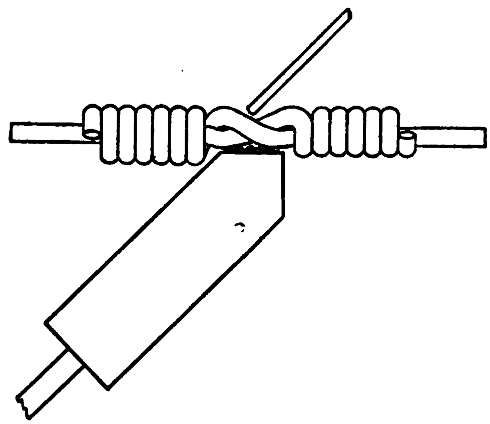
Two pieces of heavy wire.

Questions

When is it advisable to make this splice?

Why should the wire be thoroly cleaned?

PROBLEM 48



Problem

Soldering a splice.

Principle

Splice must be thoroly heated. Solder must flow freely.

Object

To insure lasting contact by excluding air.

Operations

Soldering;

Tools

Soldering iron;

Material

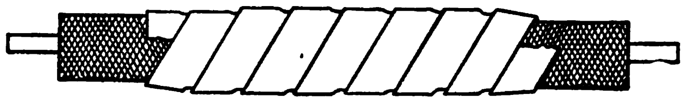
Solder, soldering paste;

Questions

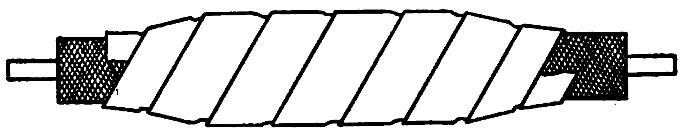
For what is the flux used?

Why should a splice be soldered?

PROBLEM 49



Rubber Tape



Rubber and Friction Tape

Problem

Taping a splice.

Principle

Rubber tape must be applied first. Both tapes must be evenly and tightly wound.

Object

To apply insulation equal in thickness to that of the wire.

Operations

Taping;

Tools

Material

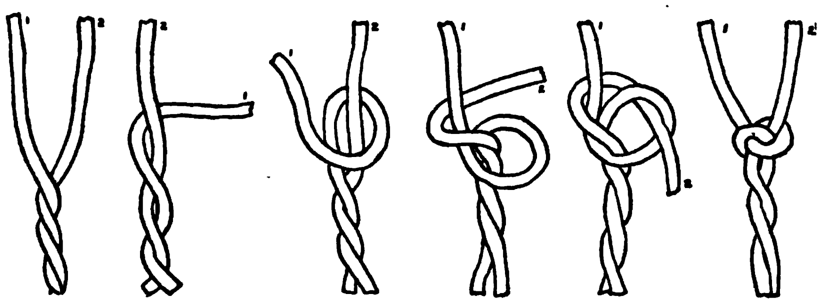
Rubber and friction tape;

Questions

Why is it necessary to tape a splice?

Why should a splice never be put in a conduit or in metal or wood molding?

PROBLEM 50



Problem

Fire underwriters' knot.

Principle

Flexible cords must be knotted so strain will not be on connections.

Object

To make a knot that will not pull thru.

Operations

Tying knot.

Tools

Material

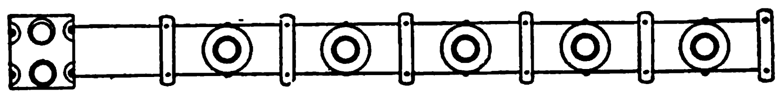
Piece of flexible cord.

Questions

Why is this particular knot desirable?

When should the insulation for connections be removed—before or after making knot? Why?

PROBLEM 51



Problem

Connections for electric lights in multiple.

Principle

The lamp's rated voltage must be the same as that of the circuit. Wires must be straight and securely fastened.

Object

To show the standard method of connecting electric lights.

Operations

Fastening, skinning, scraping, connecting, and testing.

Tools

Knife, pliers, and screw-driver.

Material

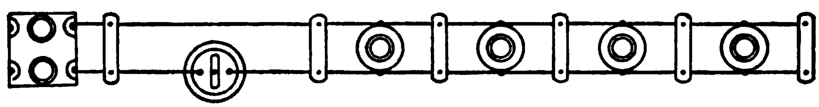
One double-pole main line cut-out, two six-ampere plug fuses, five porcelain receptacles for cleat work, six pairs porcelain cleats, No. 14 single-braid, rubber-covered wire, 1" and 2" No. 8 round-head wood screws.

Questions

What is the greatest distance allowed between cleats?

Why are cleats placed at the end of a line?

PROBLEM 52



Problem

Connections for single-pole switch control.

Principle

One side of line must be open.

Object

To show the mounting and connections of a single-pole snap switch.

Operations

Tools

Material

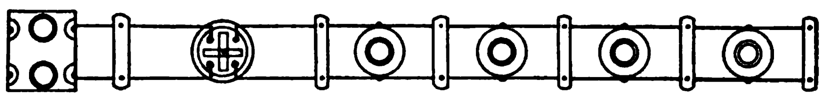
One single-pole 125-volt five-ampere snap switch, porcelain sub-base and 2" No. 6 flat-head wood screws;

Questions

Why do you mount switch on sub-base?

If the switch became short-circuited, what would be the result? (See fore-notes)

PROBLEM 53



Problem

Connections for double-pole switch control.

Principle

Both sides of line must be open.

Object

To show the operations and connections of a double-pole snap switch.

Operations

Tools

Material

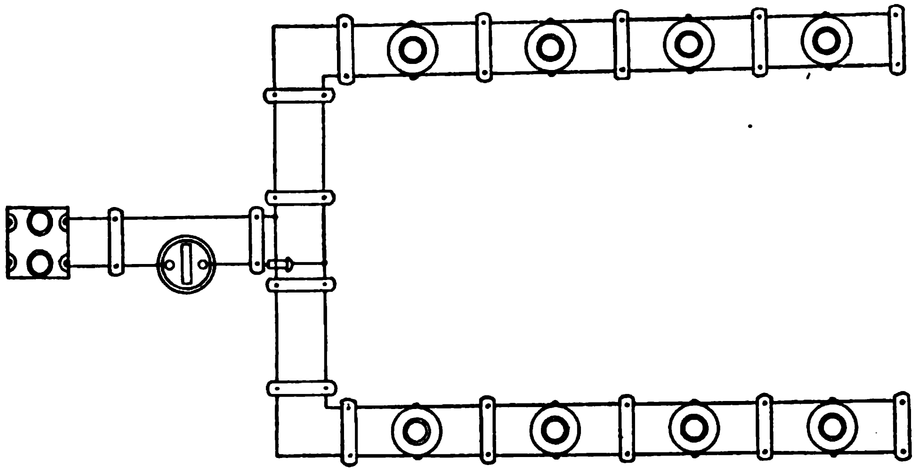
One double-pole 125-volt five-ampere snap switch;

Questions

What would be the result if the live sides of the switch became short-circuited?

When is a double-pole switch required?

PROBLEM 54



Problem

Connections for double-branch circuit.

Principle

Porcelain tubes are required where opposite polarity lines cross and must be securely fastened.

Object

To show the use of a double-branch and a porcelain tube.

Operations

Splicing, soldering, and taping;

Tools

Soldering iron;

Material

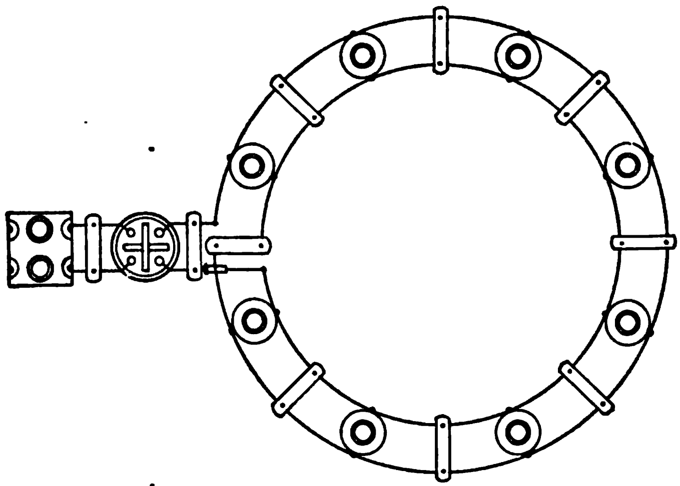
One 3"x5/16" porcelain tube, rubber and friction tape, solder, and paste;

Questions

Why must the tube be securely fastened?

Why is it important that you put the tube on the lower wire?

PROBLEM 55



Problem

Connections for circle circuit, (loop system).

Principle

Equal pressure must be maintained thruout entire circuit.

Object

To show the connections for a practical equal-pressure circuit.

Operations

Tools

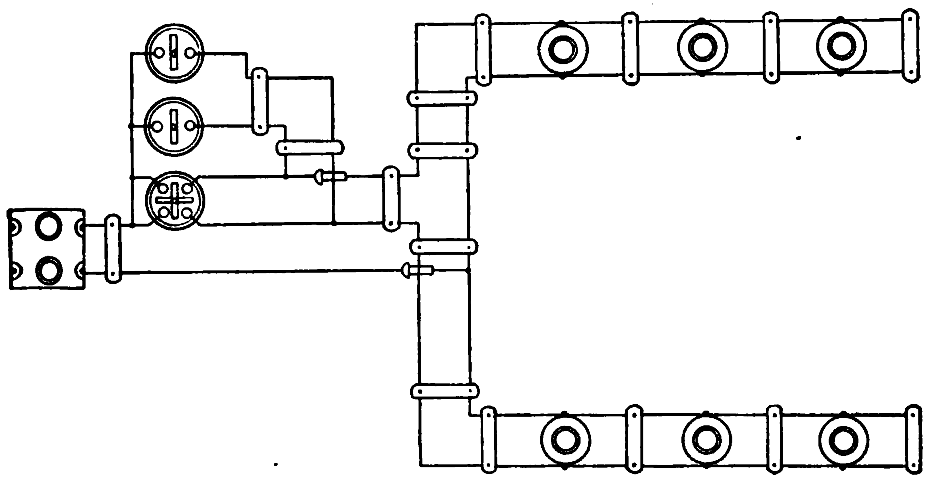
Material

Questions

Why is it important to have equal pressure on a circuit?

Which system, the loop or closet, gives the best result? (See fore-notes)

PROBLEM 56



Problem

Connections for special double-controlled circuit.

Principle

Lights must be connected so that the rows may be controlled separately or simultaneously.

Object

To show one of the various combinations of single-pole and double-pole switches.

Operations

Tools

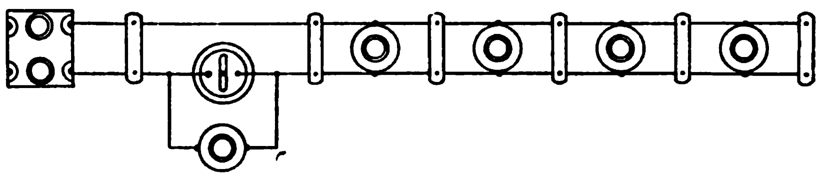
Material

Questions

Would circuit be considered single- or double-pole?

If the double-pole switch failed to light one row, where would you look for the trouble?

PROBLEM 57



PILOT LIGHT

Problem

Connections for pilot light circuit.

Principle

Series multiple connection.

Object

To show a positive and economical pilot light circuit.

Operations

Tools

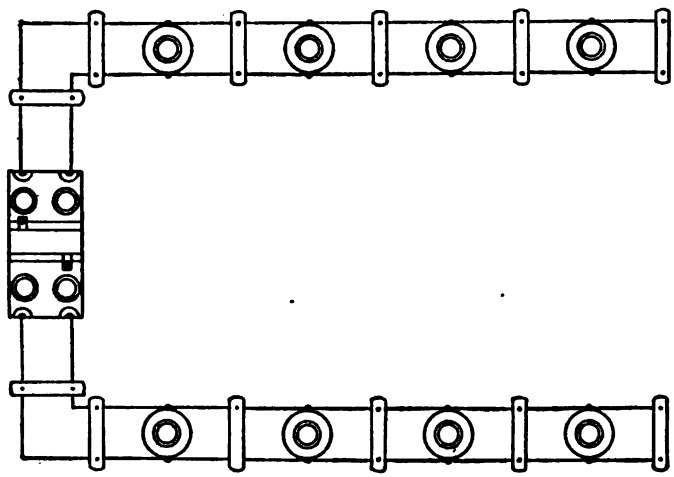
Material

Questions

Is the pilot light in series or parallel with the four lights of the circuit?

Would the pilot light be brighter or dimmer if four more lights were added to the circuit? (See fore-notes)

PROBLEM 58



Problem

Connections for double-branch cut-out.

Principle

Multiple branches of tree system.

Object

To show the standard and economic method of protecting and distributing circuits.

Operations

Tools

Material

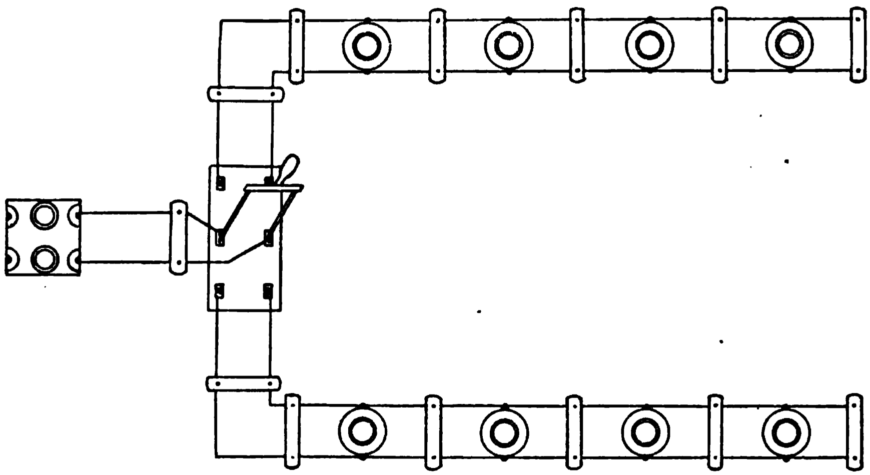
One double-pole double-branch plug cut-out.

Questions

When is a double-branch cut-out necessary?

What advantage has a double-branch over two single-branch cut-outs?

PROBLEM 59



Problem

Connections for double-pole double-throw switch control.

Principle

Switch must select and eliminate interference of circuits.

Object

To show how a double-pole double-throw switch can be used.

Operations

Tools

Material

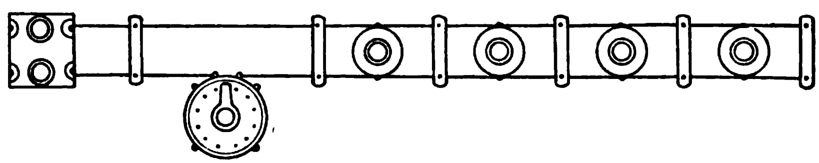
One double-pole double-throw knife switch;

Questions

If the positive line of one circuit and the negative line of the other became grounded, would it cause a short-circuit?

Show how this circuit can be controlled by a single-pole double-throw switch? (See fore-notes)

PROBLEM 60



Problem

Connections for rheostat control.

Principle

The current strength is inversely proportional to the resistance.

Object

To show method of dimming lights.

Operations

Tools

Material

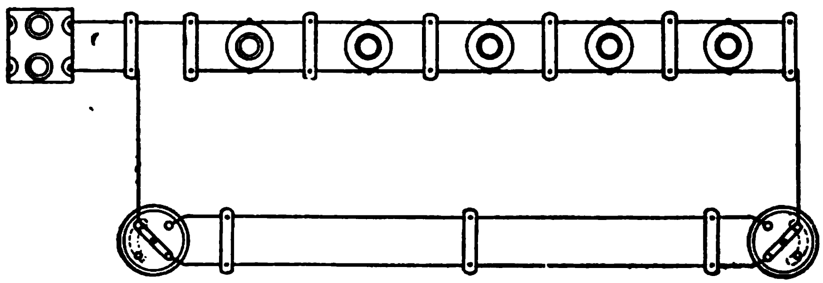
One 100-ohm rheostat;

Questions

Show inside connections of rheostat?

Why does rheostat dim lights?

PROBLEM 61



Problem

Connections for three-way switch circuit.

Principle

Either switch must control lights.

Object

To show that lights may be controlled from two places.

Operations

Tools

Material

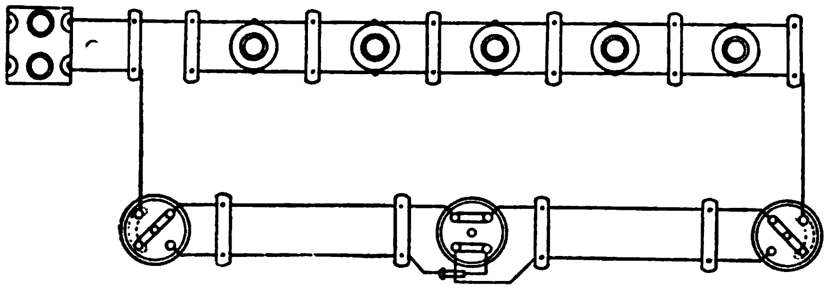
Two three-way switches;

Questions

Are three-way switches considered as single- or double-pole?

Show the two different positions of switches giving current to lights. (See fore-notes)

PROBLEM 62



Problem

Connections for three- and four-way switch circuit.

Principle

Either switch must control lights; four-way switch must cross wires between three-way switches.

Object

To show that lights may be controlled by three or more switches.

Operations

Tools

Material

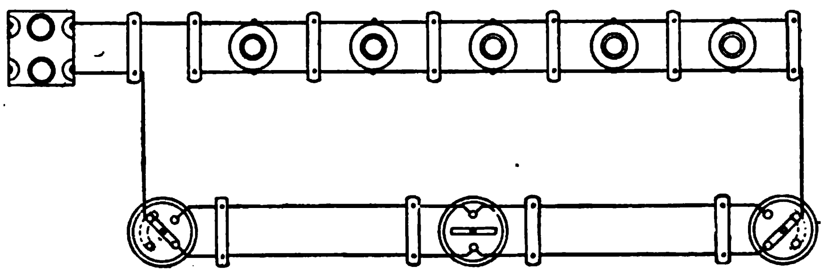
One four-way switch;

Questions

Show the four different positions of switches giving current to lights.

How would you add another four-way switch to the circuit? (See fore-notes)

PROBLEM 63



Problem

Connections for three-way switch circuit with single-pole master switch control.

Principle

When master switch is on, three-way switches have no control of circuit.

Object

To show how the master switch controls the circuit.

Operations

Tools

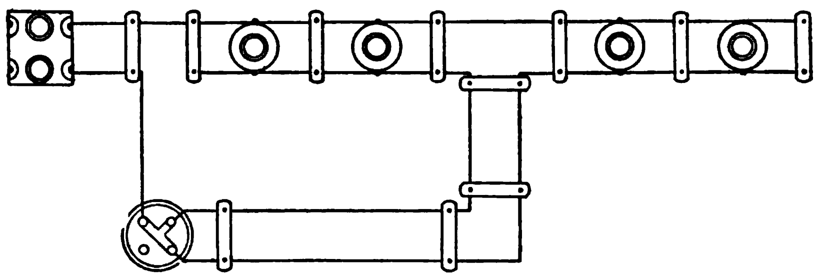
Material

Questions

How does the master switch control the circuit?

If the master switch became short-circuited, what would be the result? (See fore-notes)

PROBLEM 64



Problem

Connections for two-circuit electrolier switch.

Principle

Switch must select lights desired.

Object

To show one of the various kinds of two- three- and four-circuit, electrolier switches, giving almost any desired combination.

Operations

Tools

Material

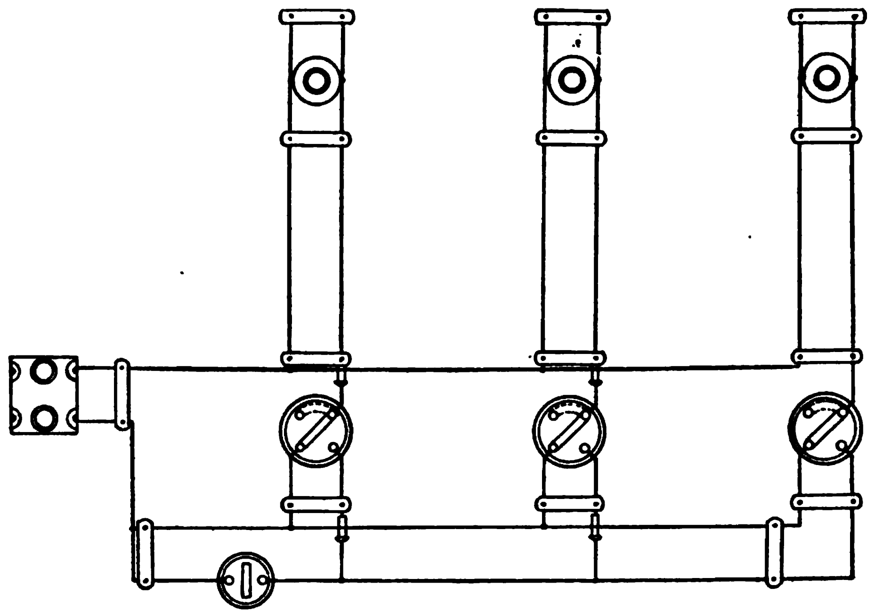
One two-circuit electrolier switch;

Questions

Show the four different positions of the switch levers.

Show how you would change the connections, so that one lamp would light on the first position and three lamps on the second. (See fore-notes)

PROBLEM 65



Problem

Connections for burglar-alarm system.

Principle

Lamps can be lighted separately and simultaneously.

Object

To show how the principle is accomplished by changing single-pole to three-way switches and connecting the dead side to the master switch.

Operations

Tools

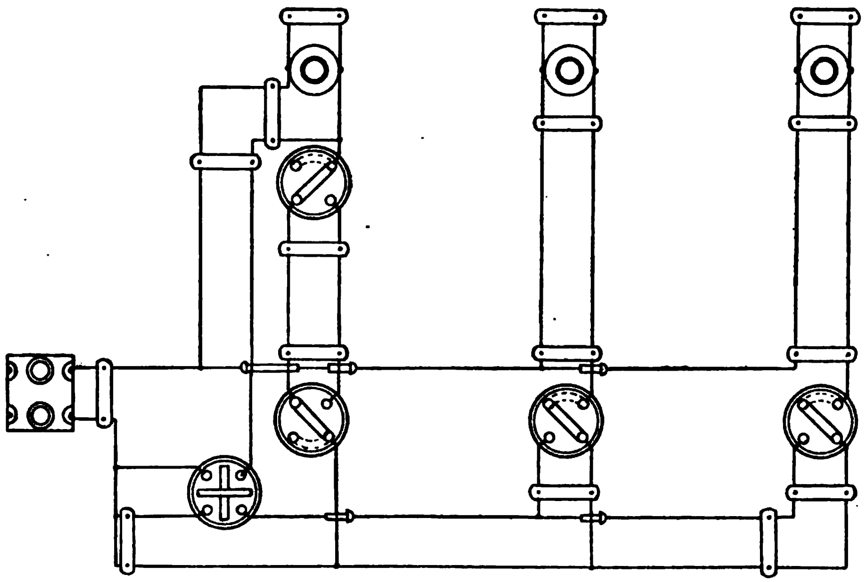
Material

Questions

How many 60-watt lamps would the master switch be allowed to control?

If the master switch were on, could you turn off the lamps from their individual switches?

PROBLEM 66



Problem

Connections for burglar alarm system, which includes a three-way switch circuit.

Principle

All lamps, including the three-way switch circuit, can be controlled separately or simultaneously.

Object

To show that when a three-way switch circuit is included, the master switch must be double-pole.

Operations

Tools

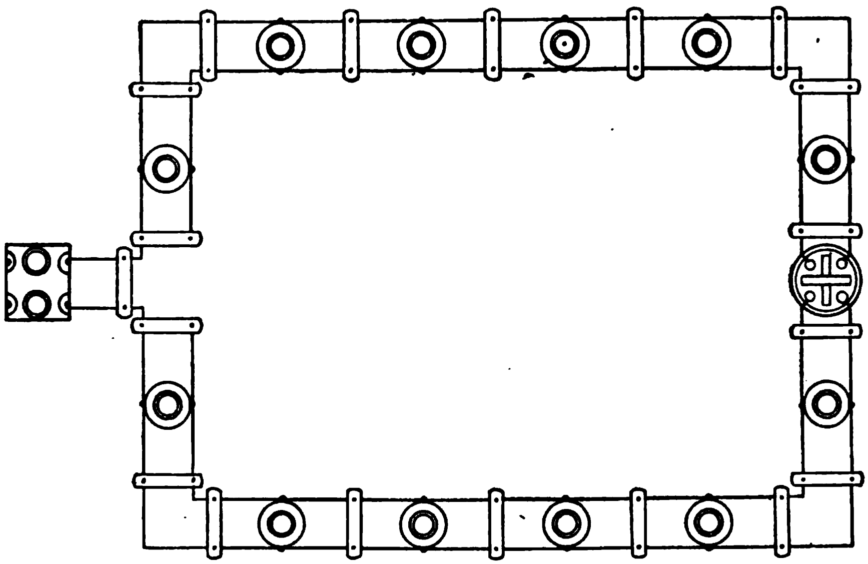
Material

Questions

How many wires run to the master switch?

Explain why it is necessary to use a double-pole master switch. (See fore-notes)

PROBLEM 67



Problem

Connections for controlling lights, opposite from feed side of room.

Principle

The live positive and negative must be on opposite sides of room.

Object

To show how a switch can be moved from one side of a room to the other without running additional wires.

Operations

Tools

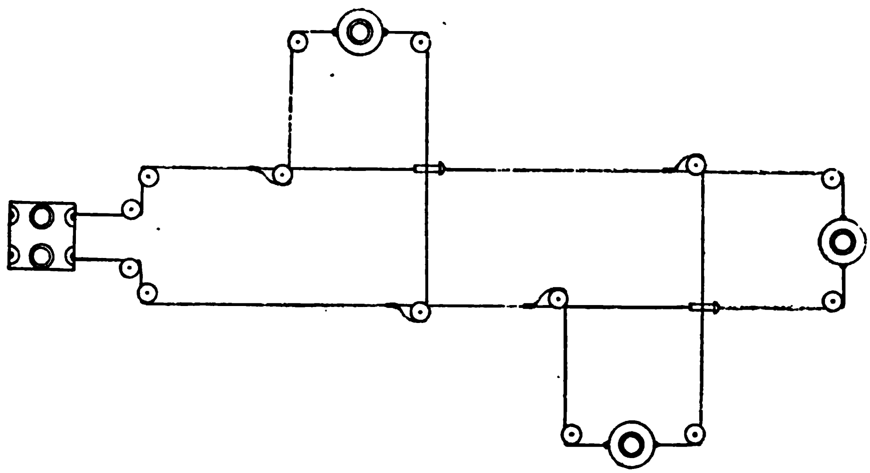
Material

Questions

Why does not the switch cause a short circuit?

If the switch were off and the two wires on one side of the room became short circuited, what would be the result?

PROBLEM 68



Problem

Supporting taps and corners in knob and tube work.

Principle

All wires must pass thru the insulators so that the strain will be on the screw.

Object

To have wires properly supported.

Operations

Tools

Material

No. 5½ porcelain split insulators, 2¼" No. 10 flat-head wood screws;

Questions

What is the shortest distance required between wires?

What is the longest distance required between supports?

PROBLEM 69

Problem

Supporting wires running along and thu joist.

Principle

Tubes must be at a slight angle with heads at highest point. Wire must be tight in all cases.

Object

To have wires properly secured.

Operations

Tools

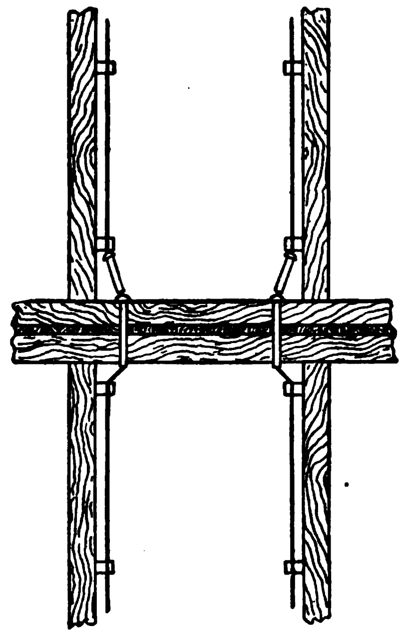
Material

Questions

Why should the tubes be at a slight angle with heads at highest point?

What would you do in case of a wire running near gas pipe?

PROBLEM 70



Problem

Running wires from one floor to another.

Principle

Wires must be protected by at least a four-inch porcelain tube.

Object

To protect wires when subjected to dropping of plaster, by plaster tube.

Operations

Tools

11/16" wood bit and brace;

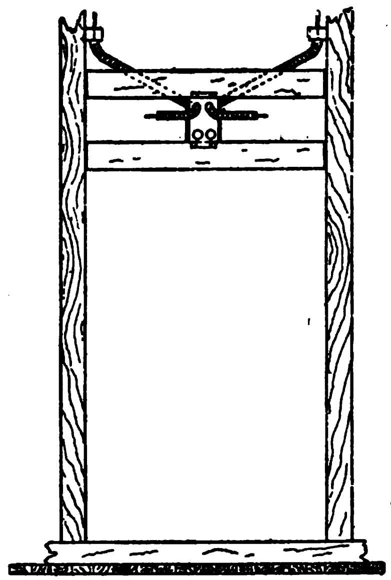
Material

Questions

Where is it necessary to use a plaster tube?

Why should the tube be at least 4 inches long?

PROBLEM 71



Problem

Locating and supporting switch boxes.

Principle

Boxes must be straight and securely and properly fastened.

Object

To have the box flush with the face of the finished wall.

Operations

Measuring, sawing, and fitting;

Tools

Saw;

Material

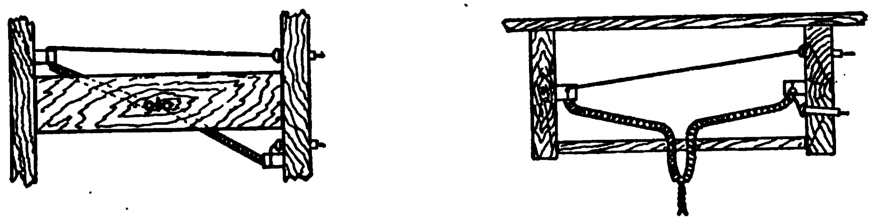
One A A single switch box, wire duct (circular loom), four ½" No. 5 flat-head wood screws;

Questions

Unless otherwise specified, at what height from the floor must the switch box be placed?

What distance must the switch box project beyond the face of the stud? (See fore-notes)

PROBLEM 72



Problem

Installing wires and support for straight electric fixtures.

Principle

Supporting board must be parallel and one-fourth inch above the lower edge of the joist.

Object

To have the support securely and properly fastened so that fixture will be firm.

Operations

Tools

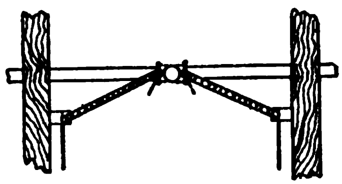
Material

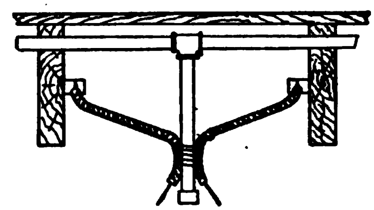
Questions

Why is support placed one-quarter inch above lower edge of joist?

Why are the holes, for circular loom, bored about two inches apart?

PROBLEM 73





Problem

Supporting wires for combination fixtures.

Principle

Circular loom must be bound securely to gas pipe.

Object

To protect wires from coming in contact with gas pipe.

Operations

Binding;

Tools

Material

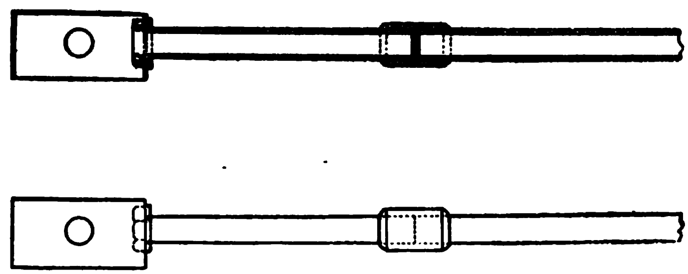
No. 14 bare wire;

Questions

Why is the circular loom bound to the gas pipe?

Why are insulating joints required on fixtures supported by gas pipe?

PROBLEM 74



Problem

Coupling of conduit to conduit or junction boxes.

Principle

All ends of conduit must be reamed.
Enameled conduit must have threads recut.
End of conduit must butt inside of coupling.

Object

To have a smooth race way mechanically and electrically secure.

Operations

Reaming, threading;

Tools

Burring reamer, stocks and dies, gas pliers;

Material

Conduit, outlet box, locknut, bushings, and coupling all the same size, 3/8" holdfast.

Questions

If wires were pulled in an unreamed conduit, what would be the result?

Why should threads on enameled conduit be recut?

PROBLEM 75

Problem

Making twist splice in outlet box.

Principle

In case of break, wire must be long enough to make another splice.

Object

To show an efficient and economic method of splicing.

Operations

Tools

Material

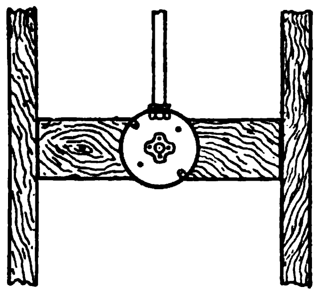
No. 14 Duplex wire.

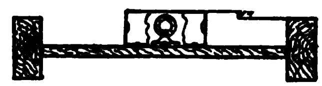
Questions

When splitting Duplex wire, why is it necessary to be careful?

Why is this splice efficient and economic?

PROBLEM 76





Problem

Locating and supporting outlet boxes.

Principle

Boxes must be straight and securely and properly fastened.

Object

To have the boxes flush with face of finished wall.

Operations

Tools

Material

Questions

Why should box be flush with face of finished wall?

For what is the holdfast used?

Standard Sizes of Conduits for the Installation of Wires and Cables

As adopted and recommended by The National Electrical Contractors' Association of the United States.

Conduit sizes based on the use of not more than three 90 degree elbows in runs taking up to and including No. 10 wires; and two elbows for wires larger than No. 10. Wire No. 8 and larger are stranded.

NUMBER OF WIRES IN SYSTEM

Size B. & S.	Cap'y Amps.	One wire in a conduit. Size conduit, in. Inter'l.	Exter'l.	Two wires in a conduit. Size conduit, in. Inter'l.	Extern'l.	Three wires in a conduit. Size conduit, in. Inter'l.	Exter'l.	Four wires in a conduit. Size conduit, in. Inter'l.	Exter'l.
14	15	½	.84	½	.84	½	.84	¾	1.05
12	20	½	.84	¾	1.05	¾	1.05	¾	1.05
10	25	½	.84	¾	1.05	¾	1.05	1	1.31
8	35	½	.84	1	1.31	1	1.31	1	1.31
6	50	½	.84	1	1.31	1¼	1.66	1¼	1.66
5	55	¾	1.05	1¼	1.66	1¼	1.66	1¼	1.66
4	70	¾	1.05	1¼	1.66	1¼	1.66	1½	1.9
3	80	¾	1.05	1¼	1.66	1¼	1.66	1½	1.9
2	90	¾	1.05	1¼	1.66	1½	1.9	1½	1.9
1	100	¾	1.05	1½	1.9	1½	1.9	2	2.37
0	125	1	1.31	1½	1.9	2	2.37	2	2.37
00	150	1	1.31	2	2.37	2	2.37	2½	2.87
000	175	1	1.31	2	2.37	2	2.37	2½	2.87
0000	225	1¼	1.66	2	2.37	2½	2.87	2½	2.87
CM.									
250,000	237	1¼	1.66	2½	2.87	2½	2.87	3	3.5
300,000	275	1¼	1.66	2½	2.87	2½	2.87	3	3.5
400,000	325	1¼	1.66	3	3.5	3	3.5	3½	4.
500,000	400	1½	1.9	3	3.5	3	3.5	3½	4.
600,000	450	1½	1.9	3	3.5	3½	4.		
700,000	500	2	2.37	3½	4.	3½	4.		
800,000	550	2	2.37	3½	4.	4	4.5		
900,000	600	2	2.37	3½	4.	4	4.5		
1,000,000	650	2	2.37	4	4.5	4	4.5		
1,250,000	750	2½	2.87	4½	4.5	4½	5.		
1,500,000	850	2½	2.87	4½	5.	5	5.56		
1,750,000	950	3	3.5	5	5.56	5	5.56		
2,000,000	1,050	3	3.5	5	5.56	6	6.62		

DUPLEX WIRE

14	15	½	.84	¾	1.05	1	1.31	1	1.31
12	20	½	.84	¾	1.05	1	1.31	1¼	1.66
10	25	¾	1.05	1	1.31	1¼	1.66	1¼	1.66

EXAMPLE—To ascertain the size of conduit for three No. 4-0 wire, follow down the wire column to No. 4-0 and then across to the section headed "Three wires in a conduit" and it will be seen that 2½-inch conduit is the size to use and that the external diameter is 2.87 inches.

Standard Sizes of Conduits for the Installation of Wires and Cables (Continued)

Conduit sizes based on the use of not more than three 90 degree elbows in runs taking up to and including No. 10 wires; and two elbows for wires larger than No. 10. Wires No. 8 and larger are stranded.

3-WIRE CONVERTIBLE SYSTEM

Size of Wires. 2-wire. Size B. & S.	1-wire. Size B. & S.	Size conduit, ins. Internal.	External.
14	10	¾	1.05
12	8	¾	1.05
10	6	1	1.31
8	4	1	1.31
6	2	1¼	1.66
5	1	1¼	1.66
4	0	1½	1.9
3	00	1½	1.9
2	000	1½	1.9
1	0000	2	2.37
0	250,000	2	2.37
00	350,000	2½	2.87
000	400,000	2½	2.87
0000	550,000	3	3.5
250,000	600,000	3	3.5
300,000	800,000	3	3.5
400,000	1,000,000	3½	4.
500,000	1,250,000	4	4.
600,000	1,500,000	4	4.5
700,000	1,750,000	4½	5.
800,000	2,000,000	4½	5.

SINGLE-WIRE COMBINATION

Based on straight run without elbows.

NOTE—Special permission is required of the inspection department having jurisdiction for the installation of more than nine wires in the same conduit.

No. of Wires.	Size conduit, ins. Inter'l.	Exter'l.
3 No. 14 R.C. D.B. solid.......	½	.84
5 No. 14 R.C. D.B. solid.......	¾	1.05
10 No. 14 R.C. D.B. solid.......	1	1.31
18 No. 14 R.C. D.B. solid.......	1¼	1.66
24 No. 14 R.C. D.B. solid.......	1½	1.9
40 No. 14 R.C. D.B. solid.......	2	2.37
74 No. 14 R.C. D.B. solid.......	2½	2.87
90 No. 14 R.C. D.B. solid.......	3	3.5

SIGNAL SYSTEMS

Based on straight run without elbow.

No. of Wires. Size	Size conduit, Inter'l.	Exter'l.
10 No. 16 lt. ins. fixt. wire....	½	.84
20 No. 16 lt. ins. fixt. wire....	¾	1.05
30 No. 16 lt. ins. fixt. wire....	1	1.31
70 No. 16 lt. ins. fixt. wire....	1¼	1.66
90 No. 16 lt. ins. fixt. wire....	1½	1.9
150 No. 16 lt. ins. fixt. wire....	2	2.37
18 No. 18 lt. ins. fixt. wire....	½	.84
30 No. 18 lt. ins. fixt. wire....	¾	1.05
40 No. 18 lt. ins. fixt. wire....	1	1.31
100 No. 18 lt. ins. fixt. wire....	1¼	1.66
130 No. 18 lt. ins. fixt. wire....	1½	1.9
200 No. 18 lt. ins. fixt. wire....	2	2.37

TELEPHONE CIRCUITS

NOTE—The wires permissible by the telephone companies of various cities differ as to thickness of insulation, therefore the following tables give both light and heavy insulation and the headings give the trade names of the wires used.

Based on not more than two 90 degree elbows.

No. 20 braided and twisted pair switch-board or desk instrument wire.

No. of Pairs.	Size conduit, ins. Inter'l.	Exter'l.
5 Pair	½	.84
10 Pair	¾	1.05
15 Pair	1	1.31
25 Pair	1¼	1.66
35 Pair	1½	1.9
50 Pair	2	2.37

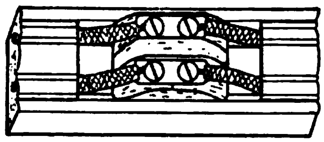
No. 19 braided and twisted pair, standard 3/32" insulation telephone wire.

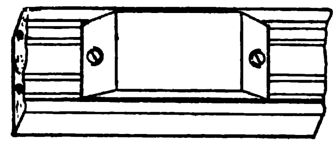
3 Pair	½	.84
6 Pair	¾	1.05
10 Pair	1	1.31
16 Pair	1¼	1.66
25 Pair	1½	1.9
35 Pair	2	2.37

Bus Bar Copper Data

Thickness Inches	Width Inches	Wgt. per Lineal Ft.	Carrying Capacity @ 1000 Amp.	@ 800 Amp.
1/16	1/2	.121	31	25
1/16	3/4	.181	47	38
1/16	1	.241	63	50
1/8	1/2	.241	63	50
1/8	3/4	.362	94	75
1/8	1	.482	125	100
1/8	1 1/4	.603	156	125
1/8	1 1/2	.723	188	150
1/8	1 3/4	.844	219	175
1/8	2	.964	250	200
1/8	2 1/2	1.21	313	250
1/8	3	1.45	375	300
1/4	1/2	.482	125	100
1/4	3/4	.723	188	150
1/4	1	.964	250	200
1/4	1 1/4	1.21	313	250
1/4	1 1/2	1.45	375	300
1/4	1 3/4	1.69	438	350
1/4	2	1.93	500	400
1/4	2 1/2	2.41	625	500
1/4	3	2.89	750	600
3/8	1	1.45	375	300
3/8	1 1/4	1.81	469	375
3/8	1 1/2	2.17	563	450
3/8	1 3/4	2.53	657	525
3/8	2	2.89	750	600
3/8	2 1/2	3.62	938	750
3/8	3	4.34	1125	900

PROBLEM 77





Problem

Connecting wires in wood molding.

Principle

Connectors must be used for extending circuits.

Object

To show fitting that takes the place of splice.

Operations

Skinning, scraping, connecting, fastening, fitting, and sawing.

Tools

Knife, pliers, screw-driver, hammer and saw.

Material

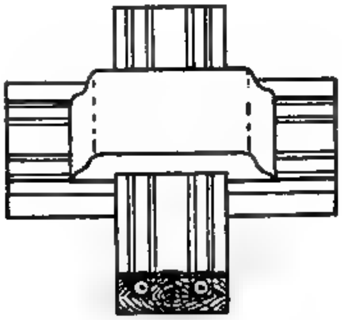
Wood molding and capping, two-wire connector, S.B.R.C. wire, 1½" No. 6 flat-head wood screws and brads.

Questions

Why is a splice not allowed in wood molding?

Is wood molding allowed in damp places? Why?

PROBLEM 78



Problem

Crossing wood molding over wood molding.

Principle

Circuits must be separated by non-combustible, non-absorptive material.

Object

To show fitting that eliminates the need of porcelain tubes.

Operations

Tools

Material

Two-wire crossover;

Questions

When must a crossover be used?

Are there any connections made in a crossover?

PROBLEM 79

Problem

Making a branch tap in wood molding.

Principle

Taplet must be used as splices are not allowed in wood molding.

Object

To show fitting that takes the place of splices.

Operations

Tools

Material

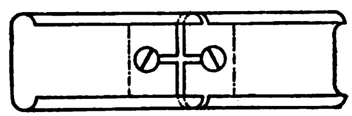
Two-pole single-branch taplet;

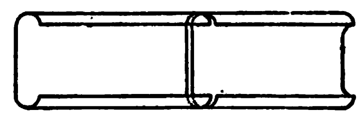
Questions

Why is a taplet safer than a splice?

How would you fasten wood molding to a brick wall?

PROBLEM 80


Proper Method


Improper Method

Problem
Coupling metal molding base.

Principle
Metal molding and rigid conduit must have a good, bonded joint.

Object
To have race ways mechanically and electrically secure.

Operations
Punching keyhole slots;

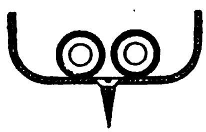
Tools
Hand punch;

Material
Metal molding; base coupling;

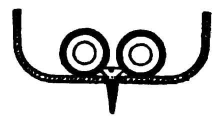
Questions
What is meant by bonding?

Why is metal molding bonded?

PROBLEM 81



Proper Method



Improper Method

Problem

Supporting metal molding base.

Principle

Screw holes must be countersunk, and base securely fastened.

Object

To show that holes must be countersunk to eliminate grounds.

Operations

Countersinking;

Tools

Countersink;

Material

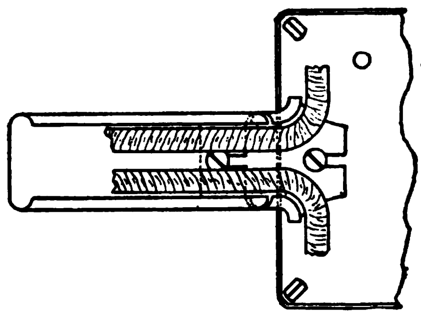
No. 8 flat-head wood screws.

Questions

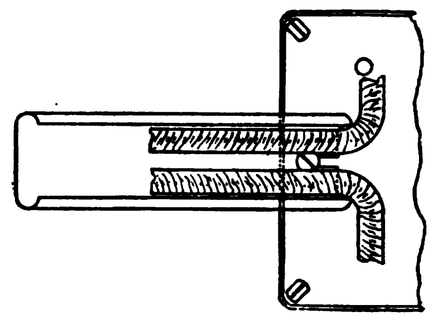
What is meant by a ground?

Would round-head wood screws eliminate need for countersinking?

PROBLEM 82



Proper Method



Improper Method

Problem

Coupling of metal molding base to junction box.

Principle

All sharp edges must be removed.

Object

To show proper fitting to accomplish the principle involved.

Operations

Tools

Material

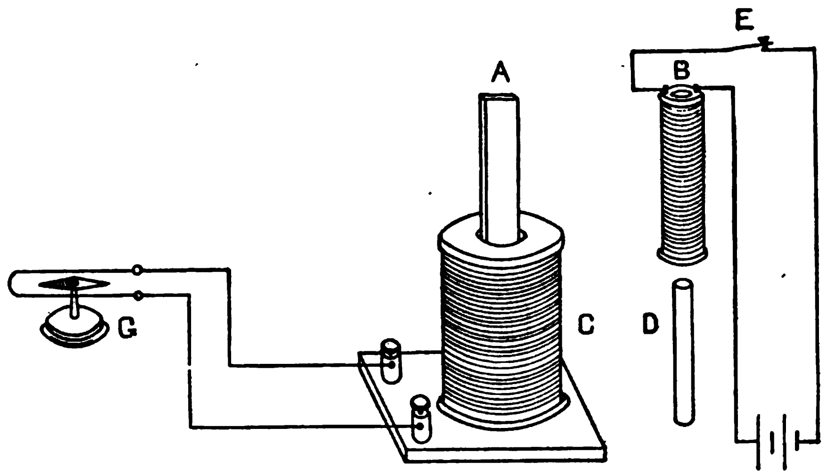
Single-clamp bushing, junction box;

Questions

What would happen if both lines became grounded?

For what are junction boxes used?

PROBLEM 83



Problem

Producing current by electro magnetic induction.

Principle

A current is induced whenever magnetic lines of force move or cut across a wire or a coil of wire. The downward movement of the bar magnet A will induce a current in one direction, while the upward movement will induce a current in the opposite direction. The more rapid the movement, the greater will be the strength of the current generator. The current ceases to flow as soon as the bar magnet is brought to rest.

If the solenoid magnet B be substituted for the bar magnet, the same principles hold true. B is termed the primary coil, and is affected by self-induction, which is due to the mutual induction of one turn of a coil of wire acting inductively upon the adjacent turns of that coil, giving momentum to the circuit. This explains the fact that the current does not instantly stop flowing when the circuit is broken at E and does not at once rise to its full value when the circuit is completed.

Whenever the current in the primary coil B, while at rest inside the secondary coil C, is either made or increased, the current is induced in the opposite direction, and when broken or diminished is induced in the same direction. This is called mutual induction. The iron core D, when placed inside the primary coil, will greatly increase the inductive effect.

G is an instrument called the "galvanometer" for detecting small electric currents.

Object

To show how current is induced in the secondary of an induction coil.

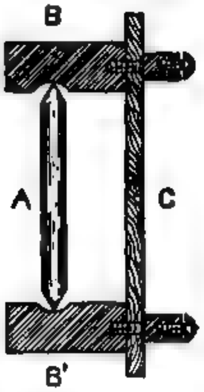
Questions

Why does the current cease to flow when the bar magnet is brought to rest?

Why does the iron core of an induction coil increase its efficiency?

What is an induction coil?

PROBLEM 64



Problem

Construction and operation of a telephone transmitter.

Principle

The sound waves or air vibrations produced by the voice cause the thin metal diaphragm C to vibrate, and the varying pressure it exerts on the carbon granules A, between the carbon buttons or electrodes B and B^1 causes a fluctuating current in the battery circuit, which is in unison with the air vibrations. D is a very soft felt or wool-like washer and is used to retain the carbon granules A. The carbon electrodes B and B^1 are usually very highly polished.

Figure to the left illustrates one of the first telephone transmitters. It consists of a carbon pencil pointed at both ends, A, which rests in circular depressions in the two carbon blocks, B and $B.^1$ The vibrations of the sounding board or diaphragm, C, vibrate the carbon pencil, causing a variable current to flow between B and $B.^1$

Object

To show how sound waves are changed into electric waves.

Questions

Explain in your own words the operation of a transmitter.

What is likely to happen if too much voltage is applied to a transmitter?

What effect would dampness have on a transmitter?

PROBLEM 85

Problem

Construction and operation of a telephone receiver.

Principle

The variable currents, or electric waves, from the transmitter, passing thru the magnet coils G and G^1 set up a fluctuating magnetization which causes the diaphragm I to vibrate in unison with the diaphragm of the transmitter. This vibration causes the air particles to vibrate and the resulting sound is identical. Permanent magnet receivers are used where the receivers are connected to the secondary of induction coils, and are therefore not magnetized by the direct current flowing in the line circuit. The resistance of an ordinary telephone receiver is about 80 ohms.

Figure to the left illustrates one of the first telephone receivers. It consists of an electro magnet G, with a soft iron core F. The diaphragm I consists of a membrane of goldbeater's skin, with a soft piece of iron attached which acts as an armature, the membrane allowing it to vibrate in front of the pole of the electro magnet. This receiver is called a direct current receiver.

Object

To show how electric waves are changed into sound waves.

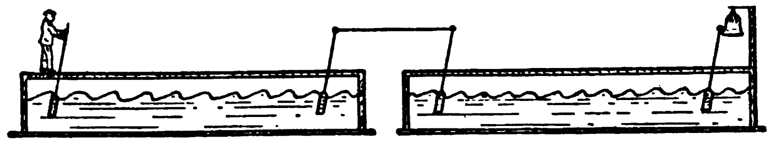
Questions

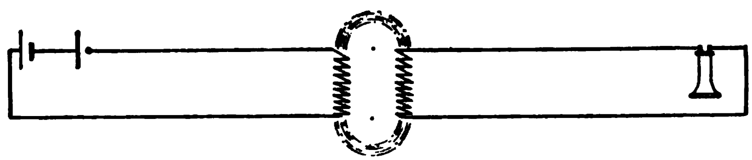
Why is the horseshoe magnet F used instead of a bar magnet?

Why must the diaphragm be made of soft iron?

Why do telephone receivers have a permanent magnet core instead of a soft iron core?

PROBLEM 86





Problem

Analogy between variable battery current and variable water flow.

Principle

The variable resistance is due to the variable contact in the transmitter. The induction coil repeats and intensifies the electric waves to the receiver. The receiver changes electric waves into sound waves.

Object

To transmit speech over wires by means of electricity.

Operations

Skinning, scraping, connecting, fastening, and testing.

Tools

Knife, pliers, screw-driver, hammer.

Material

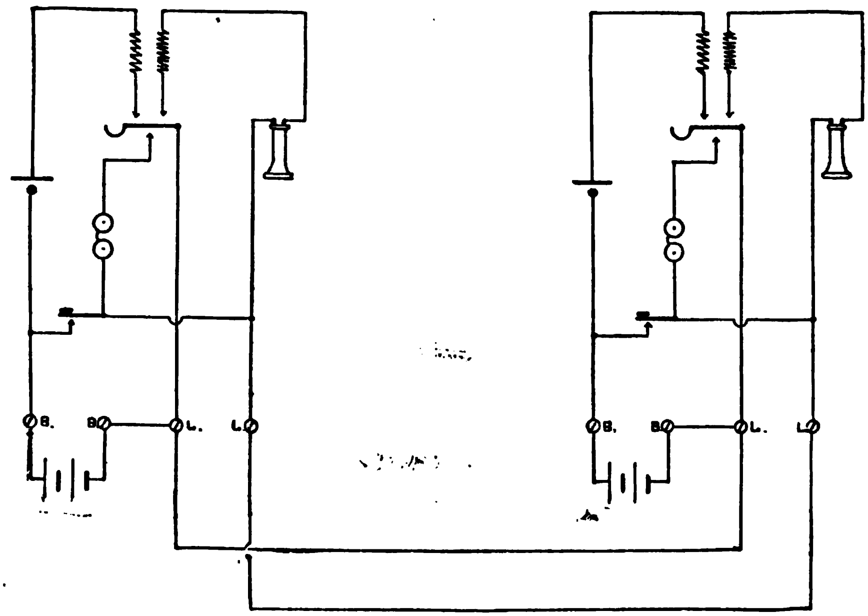
One telephone transmitter, receiver, and induction coil, two dry cells, No. 18 bell wire.

Questions

What is meant by variable current?

How does the current get from the tranmitting circuit to the receiving circuit, there being no electrical connection?

PROBLEM 87



Problem

Connections for private line battery telephone system.

Principle

All bells must ring together. All parties can listen on the line.

Object

To show that not more than three or four phones can work satisfactorily on this system.

Operations

Tools

Material

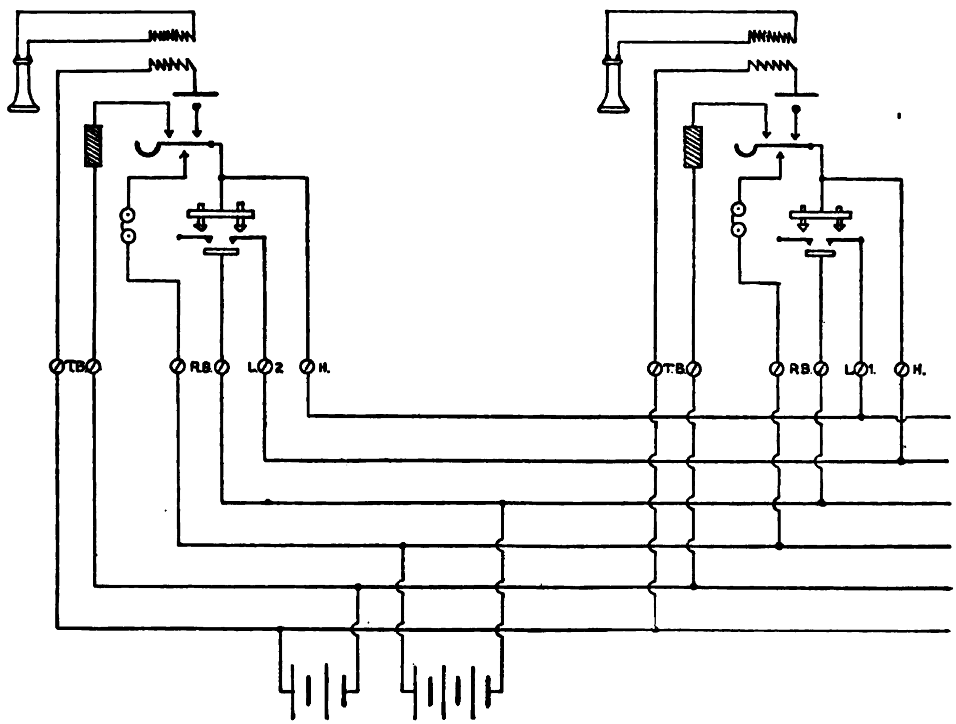
Two wall type private line battery telephones.

Questions

Why is it impracticable to use more than four phones on this system?

If the receiver is off the hook, can you be called? (See fore-notes)

PROBLEM 88



Problem

Connections for central energy inter-communicating telephone system.

Principle

Switch hook must automatically lock and release the push-button.
Each push-button must be used for both ringing and talking.
When system is idle no current must flow from either ringing or talking battery.

Object

To have system free from cross-talk.

To have batteries of sufficient capacity and to put in a dry, cool, accessible place near the center of the system.

Operations

Testing out cable.

Tools

Material

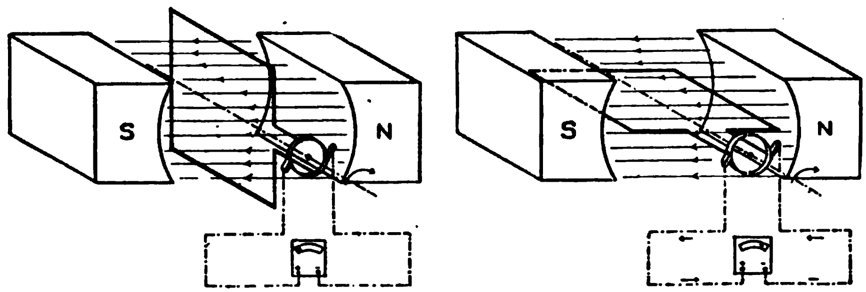
Two four-wire common-return inter-communicating central battery telephones, cable as required;

Questions

Why is choke coil used?

What circuit does the switch hook connect when receiver is on hook? When receiver is off hook?

PROBLEM 89



Problem

Connections and operation of a simple dynamo.

Principles

The fundamental law of tractive forces in electro-magnets is consequently the fundamental law of rotating forces in all electric dynamos or motors.

In order to induce a current by electro-magnetic induction, a conductor must be so moved thru a magnetic field that the number of lines of force passing thru it must be altered.

The figure to the left shows a conducting loop in a vertical position between two magnetic poles. In this position it is not cutting or altering the lines of force passing thru it, and therefore is not generating a current.

The figure to the right shows the same conducting loop in a horizontal position and moving in a clockwise direction. In this position it is cutting the greatest number of lines of force and, therefore, generating the maximum current.

A conducting loop passing in front of a north magnetic pole will have a current generated in it in one direction, and in the opposite direction while passing in front of a south magnetic pole, providing it is rotating in the same direction.

To the two semi-circular strips, or commutator bars, are connected the ends of the loop of wire; and on these bars, or segments, the brushes rest. They are placed in this position so that they change from one segment to another just as the direction of the current in the loop changes. For this reason the current in the external circuit is always in the same direction.

The difference between a generator and a motor is that in a generator the current is in the same direction as the electro-motive force, while in a motor the current is opposite to the E.M.F. of the machine.

Object

To show how a pulsating current is generated by means of a single loop of wire connected to a commutator cutting or passing thru a magnetic flux.

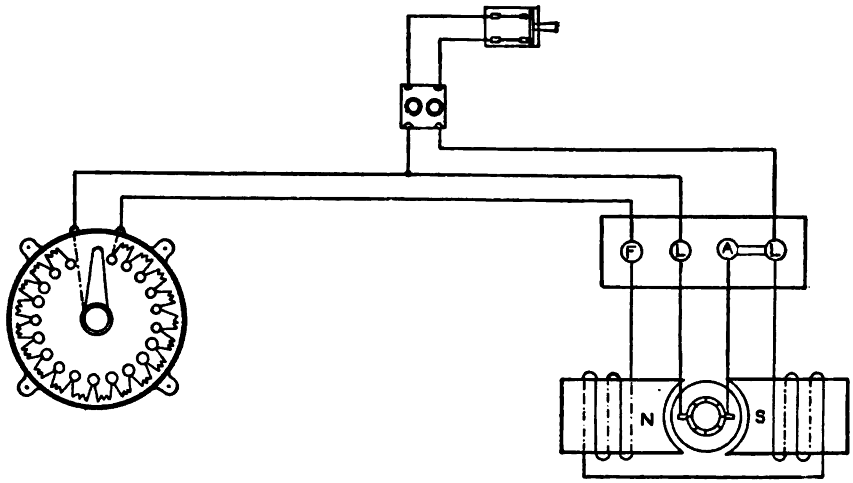
Questions

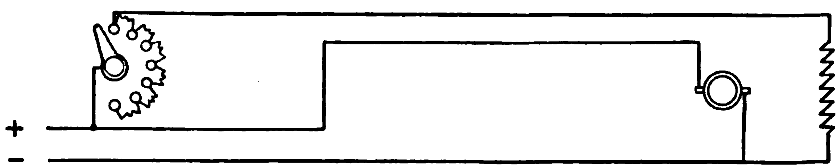
What is meant by E.M.F.?

How many times does the current reverse in the loop during one revolution?

Explain in your own words the function of a commutator?

PROBLEM 90





Problem

Connections and operation of a shunt generator.

Principles

The magnetic field flux pouring into, and emptying out of the armature conducting loops, induces an E.M.F. in those loops in proportion:

1st To the number of loops or turns on the armature.

2nd To the total magnetic field flux or lines of force.

3rd To the speed or number of revolutions per minute of the armature.

Whenever the conducting loops of the armature rotate in a magnetic field, the armature wires cut the field flux and generate an E.M.F. which tends to send a current in the opposite direction from the current causing it to rotate; therefore they oppose each other. This is called counter E.M.F. The difference between the impressed E.M.F. and the C.E.M.F.=the E.M.F. that forces the current thru the armature. This current causes a magnetomotive force which breaks up the previously established field M.M.F.'s. It is called armature reaction. The combination of the two magnetic circuits causes the leading pole edge to have its flux density strengthened in a motor, and the trailing pole edge to have its flux density strengthened in a generator. For this reason a motor pulls and a generator has to be pulled.

Object

To show how a continuous current is generated by means of a number of loops or coils of wire, properly connected to a commutator, cutting or passing thru a magnetic flux.

Questions

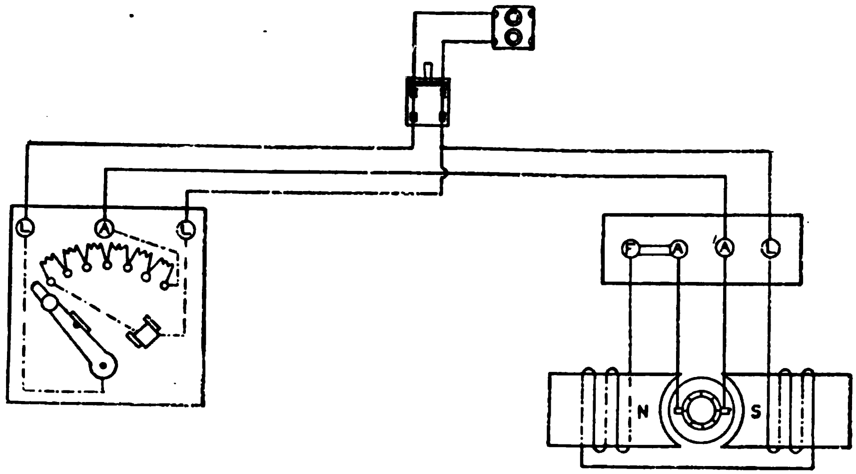
Is residual magnetism necessary for the operation of a shunt generator? Why?

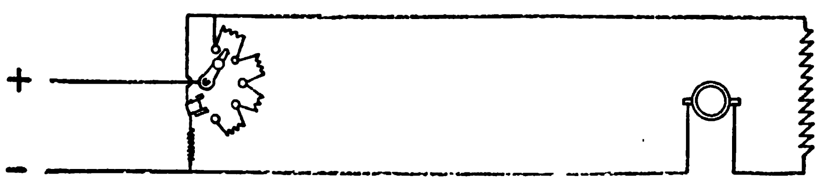
Why are the fuses and switch reversed as to location in a generator from that of a motor?

What is meant by the building up of a machine?

Explain the effects of the following on a shunt generator: (a) Increasing the number of turns on the armature. (b) Increasing the magnetic field flux. (c) Decreasing the speed of the armature.

PROBLEM 91





Problem

Connections and operation of a series-wound motor.

Principles

The attraction of the field poles for the armature poles of a motor is the cause of its armature rotation.

The total current passes thru both armature and field coils.

To reverse a series motor, reverse either armature or field connections.

The rheostat is used to diminish the effective magnetism, and thereby the speed.

With the increase of load in a series motor, the M.M.F. of the field increases, thus increasing both the flux thru the armature and the C.E.M.F., causing the speed to diminish.

Object

To show the connections, operation and use of a series motor. It may be used to great advantage in street railway service where variable speed and variable torgue are required.

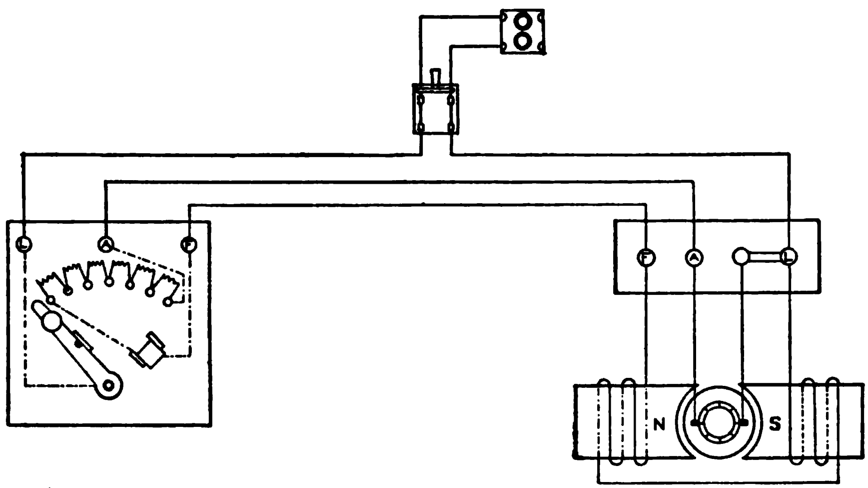
Questions

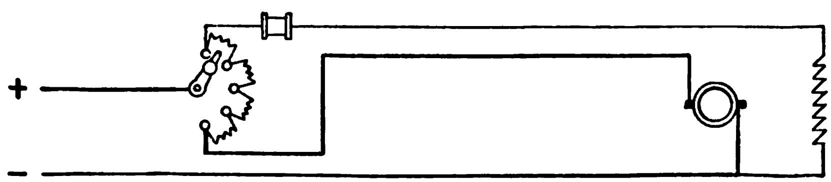
What are the advantages and disadvantages of a series motor?

How would you tell a series motor from another motor if it had no name plate?

What would happen to a series motor if it were run without a load?

PROBLEM 92





Problem

Connections and operation of a shunt-wound motor.

Principles

The greater portion of the current is used in the armature circuit, only about 5 per cent being used in the field circuit.

The starting resistance is inserted so as to avoid a sudden inrush of current. This resistance allows the armature to slowly accelerate and develop its C.E.M.F.

The small magnet on the starting box is a low voltage release, which releases the controlling arm whenever the line voltage or the voltage generated by the motor after the line is opened, is diminished to a certain degree.

With an increased load on a shunt motor, the speed is lowered. This decreases the C.E.M.F., which in turn allows more current to pass thru the armature. As the armature current increases, the torgue or twisting force of the axle increases. This process of adjustment makes the motor almost automatically self-regulating, to within 2 per cent for large motors and 5 per cent for small motors.

Object

To show the connections, operation and use of a shunt motor. It may be used to run all kinds of machinery where nearly constant speed and variable torgue are required.